

NSRP 0245

METHODS ENGINEERING WORKSHOP
FOR THE SHIPBUILDING INDUSTRY

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INSTITUTE OF INDUSTRIAL ENGINEERS

Methods Engineering Workshop
for the Shipbuilding Industry

TASK EC-23

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Date: September, 1985

This project is managed and cost-shared by the Institute of Industrial Engineers for the National Shipbuilding Research Program. The program is a cooperative effort of the Maritime Administration's Office of Advanced Ship Development, the U.S. Navy, the U.S. shipbuilding industry, and selected academic institutions.

METHODS AND ENGINEERING TERMS AND DEFINITIONS

Avoidable Delay. A delay which is under the control and responsibility of the worker.

Constant Element. An element whose work content and normal time do not vary significantly although some other aspect of the job changes.

Elemental Breakdown. A listing of work elements with individual descriptions and/or calculations for each; the separation of a work cycle.

Fair Day's Work. The amount of work that management expects daily from an employee. Expected attainment.

Fatigue Allowance. An adjustment to normal time to compensate for loss of production time due to the operator resting.

Flow Process Chart. A graphic, symbolic representation of work performed on a product as it passes through some or all of the stages of production.

Indirect Labor. Work that is not readily chargeable to or identifiable with a specific product or service.

Industrial Engineering. The design, improvement, and installation of integrated systems of people, materials, and equipment, drawing upon specialized knowledge and skill to specify, predict, and evaluate the results to be obtained from such systems.

Interference Allowance. An adjustment to standard time to compensate for idle machine time when the work cycles of the operator and two or more machines do not coincide.

Job Description. A summary of essential activities of a job abstracted from a job analysis and used in the classification of a job.

Learning Curve. A plot of productive output as a function of time where the time per unit will usually decrease as the worker becomes proficient in work performance.

Low Task. Average daywork performance under conditions of little supervisory control. Often taken to be $83\frac{1}{2}\%$ of normal task.

Methods Engineering. A collection of analysis techniques that focus attention on improving the effectiveness of people and machines, including the design of controls. "Common sense systematically applied."

Motion Economy. Use of the basic principles of the manner in which body motions are performed to simplify and reduce work content.

Nomograph. A graphical set of lines or curves representing equations arranged so that a solution can be obtained by connecting points representative of independent variables.

Normal Pace. The manual working pace that requires normal effort to perform.

Operations Analysis. A study that encompasses all procedures concerning design, operation purpose, inspection requirements, materials, material handling, setup, tools, working conditions, and methods.

Operation Process Chart. A graphic and symbolic representation of the complete sequence of producing a product showing the operations and inspections performed.

Plant Layout. The planning of plant structure, service facilities, and production facilities.

Scientific Management. "Management based on measurement plus control." F. W. Taylor.

Time Formula. A formula for determining the normal time or standard time of a task as a function of one or more variables in the task.

Unavoidable Delay. A delay which is outside the control. or responsibility of the worker.

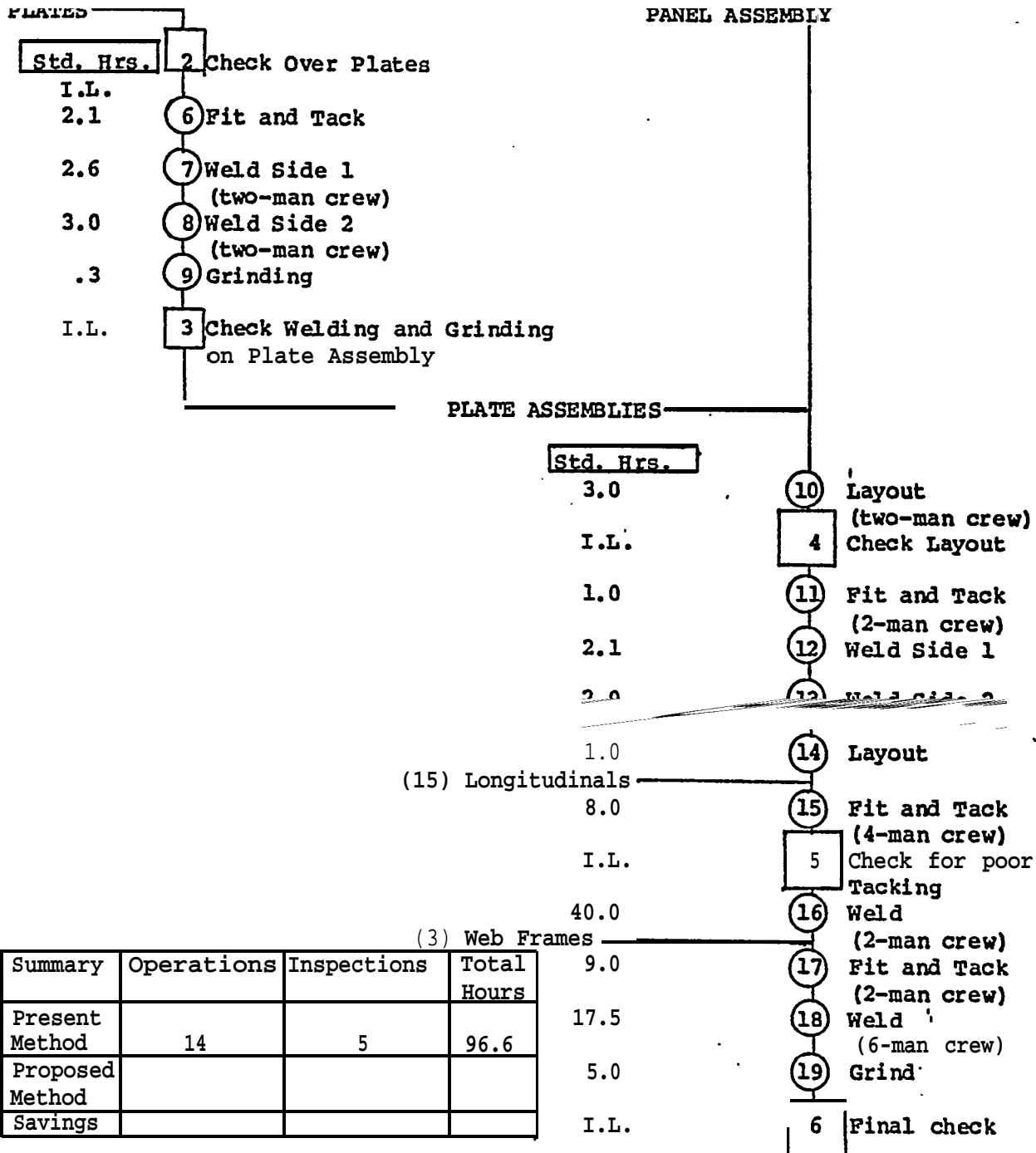
Work Sampling. A work measurement technique consisting of intermittent, instantaneous observations of work activity or delays.

Work Simplification. Improvement in work methods initiated and developed on the job as a result of methods training and/or incentives.



TYPICAL PANEL ASSEMBLY OPERATION

The operation process chart here indicates those activities for flat panel assemblies starting at the panel.





OPERATION FLOW PROCESS CHARTING - SYMBOLS AND TERMS (Slide 1)

Slide 2



Operation: Produces or Accomplishes



Operation #3

Slide 2



Transportation: Moves



Transportation #8

Slide 3



Inspection: Verifies



Inspection #2

Slide 3



Delay: Interferes



Delay #6

Slide 4

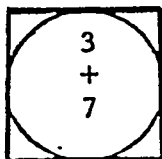


Storage: Keeps



Storage #1

Slide 4



Combined Activity:

Inspection #3 plus Operation #7



Slide 5

Subject charted: _____ Present/proposed method: _____

Drawing/part number: ____ Date charted: _____ By: _____

Sheet ____ of ____ sheets: _____ Approved by: _____

Location (Plant no., etc.): _____ Chart no. : _____
(or other information)

Slide 6

<u>Assy. Name</u>		<u>Time</u>	<u>Dept.</u>
1st Operation	1	1.6 hrs.	16
New material introduced			
2nd Operation	2	2.1 hrs.	18
1st Inspection	1	.3 hr.	50

Slide 7

<u>Part Name</u>		
.30 hr.	1	Receiving inspection
2.50 hrs.	4	Wait for dispatcher
500 ft.	14	Move to stock 50 PCS.
24.0 hrs.	6	Stay in stock until needed



Slide 8



A break in the flow process line
is shown like this.



slide 9

FLOW PROCESS CHART

SUBJECT _____ DATE _____

CHART BEGINS _____

CHART ENDS _____

SYMBOLS	DESCRIPTION	REF	DISTANCE MOVED IN FEET	UNIT OF TIME IN HOURS	UNIT TRANS TIME IN HOURS	UNIT INSPECT TIME IN HOURS	DELAY TIME IN HOURS	STORAGE TIME IN HOURS
○⇨D□▽								
○⇨D□▽								
○⇨D□▽								
○⇨D□▽								
○⇨D□▽								
○⇨D□▽								
○⇨D□▽								
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Load the slides into a slide carousel and review before starting the study.
When reviewing, write down each activity as follows:

Working Activities

Tally

Total

Receiving instructions
Tacking
Removing slag
Material handling
Miscellaneous work activities

Not-Working Activities

Personal
Not in area
Talk to other worker

Total Observations

Once the activity categories have been established, progress through the complete set of slides on an 8-second interval per slide and mark the appropriate categories. The random placement of slides in the carousel represents the random time observation techniques. However, if you choose, a group of people can be given random time to observe the slides with a narrator calling out times on a 5-second count. The results will be the same in either case.

When the observations have been completed, add the mark for each activity and also the total marks for the study. With this data, the time percentage for each activity can be calculated: $\text{No. Reading/Activity} \div \text{No. Reading for Study Activity} = \text{Percent}$.

Work Sampling Study Results

<u>Work Activities</u>	<u>Percent</u>
Receiving instructions	2
Tacking	40
Removing slag	12
Material handling	.6
Miscellaneous work activities	8
Total	68
<u>Not-Working Activities</u>	<u>Percent</u>

Total



OPERATION FLOW PROCESS CHARTING - SYMBOLS AND TERMS (slide 1)

slide 2

Slide List

No.	Description
1	Title slide: Work Sampling Study: Fitting operation
2	Receive instructions
3	Tacking
4	Tacking
5	Tacking
6	Tacking
7	Remove slag
8	Material handling
9	Material handling (wait on crane)
10	Miscellaneous activity (operator walking)
11	Miscellaneous activity (operator standing)
12	Personal (reading paper) .
13	Not in area
14	Talk to other worker
15	Tacking (#3)
16	Tacking (#5)
17	Remove slag
18	Personal (reading paper)
19	Miscellaneous activity (operator walking)
20	Tacking (#4)
21	Tacking (#6)
22	Tacking (#3)
23	Tacking (#4)



24 Tacking (#5)
25 Tacking (#6)
26 Material handling
27 Talk to other worker
28 Not in area
29 Tacking (#5)
30 Remove slag
31 Remove slag
32 Miscellaneous activity (operator standing)
33 Tacking (#4)
34 Tacking (#5)
35 Tacking (#3)
36 Tacking (#6)
37 Personal (reading paper)
38 Personal (reading paper)
39 Tacking (#6)
40 Personal (reading paper)
41 Not in area
42 Talk to other worker
43 Tacking (#3)
44 Remove slag
45 Talk to other worker
46 Remove slag
47 Personal (reading paper)
48 Not in area
49 Personal (reading paper)



50 Tacking (#4)

51 Not in area

RATIO-DELAY

Ratio-delay is an abbreviated form of the work sampling study in that only two activities are observed: working and not working. Ratio-delay compares the operators observed working with the total operators observed--a sort of "heads up-heads down" comparison. This form of work sampling is performed when detailed activities are not required and when interest is in what amount of time is spent working and not working. All the rules that govern work sampling also apply to ratio-delay.

Ratio-Delay Exercise

The slides that were used for the work sampling study can also be used for the ratio-delay exercise. The same procedures should be followed; however, only two categories are of interest: working and not working. The results of your study should have the working activities at 68% and not-working activities at 32% of the time.



Methods Engineering Workshop for the Shipbuilding Industry

Manual Contents

Overview

Section I Productivity

Section II Methods Analysis and Improvement

Section III Selecting the Work To Be Studied

Section IV Record and Analyze the Method

Section V Record and Measure the Time of an Operation

Section VI Examine the Facts

Section VII Develop an Improved Method

Section VIII Selling the Improvement and Maintaining It

Supplemental Materials





Overview

Guidesheet for Follow-on Training

Workshop Introduction 1

Instructors 3

Shipyard Industrial Engineering 4





METHODS ENGINEERING WORKSHOP FOR THE SHIPBUILDING INDUSTRY
GUIDESHEET FOR FOLLOW-ON TRAINING



GENERAL INFORMATION

The purpose of the Methods Engineering Workshop is to train shipyard personnel in the techniques of methods improvement with the ultimate goal of improving manufacturing productivity in their yards. The workshop materials in front of you are the end results of several hundred hours of research and development by specialists in training, industrial engineering, and methods improvement. Properly used, they can be the core of a valuable and effective program for IE technicians, industrial engineers, production engineers, foremen, supervisors, and operations managers. The key to their proper use, however, is an understanding of the materials and how they can be integrated into a training program.

COURSE MANUAL

The 104-page manual has been designed as both a student reference manual and an instructor guidebook. The course manual consists of eight (8) major sections. The titles of these sections are:

- I. Productivity
- II. Methods Analysis and Improvement
- III . Selecting the Work to be Studied
- IV Record and Analyze the Method
- v. Record and Measure the Time of an Operation
- VI. Examine the Facts
- VII . Develop an Improved Method
- VIII . Selling the Improvement and Maintaining It

Each of these major sections contains reference material written specifically for the shipbuilding industry, providing a more familiar reference for reinforcing the concepts taught in the workshop. In addition, many sections include supplemental texts, articles, charts, and tables to augment the reference material.

This guidesheet is designed for use by workshop attendees who wish to conduct subsequent training within their shipyards.

Before continuing with this guidesheet, read through the manual to familiarize yourself with its contents. While you are reviewing the material, notice that each section has its own Table of Contents which includes a listing of the additional supplementary materials. In a later section of this guidesheet entitled "USING THE COURSE MATERIALS," references will be made to the course manual.

HOW TO DEVELOP A TRAINING PROGRAM WITHIN YOUR SHIPYARD

The most important items to consider when developing a program are:

1. The agenda or day-by-day activities.
2. The use of the course materials.
3. The equipment needed to present the program.



PROGRAM AGENDA

The original pilot workshop was designed for and presented in a five-day format. To cover all the material in the manual, 40 hours of class time will be required. It is not necessary to teach the program in five consecutive days, however. Because of personnel and shift schedules, you may find it more appealing and flexible to teach the program over a period of weeks. Some guidelines to consider are:

1. The course manual presents the basic fundamentals of industrial engineering techniques. The material is presented in a step-by-step format that is most effective when conducting a methods improvement study. It will provide the most value to the student if the outline is followed. However, each section is independent and can be taught separately if so desired. It is a good idea to devote a minimum of 24-30 hours of training time for this material.
2. To make the program more effective, allow the participants to practice some of the techniques discussed in the manual by going out into the yard and applying the techniques (e.g., linear responsibility charting, operations analysis, group timing technique, work sampling, etc.)
3. Section VII of the course manual should be covered in approximately six hours. These case studies were developed at various shipyards around the country and will, most likely, be applicable to the operations in your yard.
4. After completing the case study section, assign problems to the participants. The problems can be similar to those found in the manual. Allow the participants five to ten working days to solve the case study problems and to document them for discussion in a classroom environment.

Regardless of the way you structure your program, always look at your training agenda as temporary. Each time you conduct the program, reevaluate it, perhaps with the students, and improve it. Don't assume that your first agenda will be perfect. Always remember that the agenda, like the employees you train, is a dynamic changing element and must be evaluated frequently to be sure that it is effective.

USING THE COURSE MATERIALS

The next item to consider when structuring a program is the way you will integrate the materials into the workshop. Some helpful suggestions are listed here.

OVERVIEW of the course manual

Pages 1-4 are introductory in nature. As a result, these first few pages can be read by the participants outside of the class.

SECTION II of the course manual

Pages 5-7 discuss what productivity is and the need for it in order for the Industry to survive.



SECTION III of the course manual

The purpose of section III is to get the participants acclimated to method engineering terminology.

Pages 8-9 address the methods improvement attitude. Methods improvement is a continuing process as long as an operation exists. The ultimate improvement is to eliminate an operation.

Pages 10-12 discuss the two main blocks of methods engineering, methods study and work measurement. Methods study deals with the examination of work content of a task while work measurement is concerned with the time it takes to perform a task.

Pages 13-14 are lists of methods engineering terms. Notice that there is a set of terms with definitions at the back of this follow-on guidesheet. This provides you with the tools to conduct a short quiz on terminology.

Included is a copy of the American National Standards Institute terminology manual for Work Measurement and Methods. This is supplemental and can be used as a reference or to expand your quiz on methods engineering terms.

Page 15 states the primary objectives of methods study.

Page 16 highlights the basic procedures for conducting a methods improvement study. The eight steps called out on this page set the stage for the remainder of the workshop.

<u>STEPS</u>	<u>MANUAL SECTION</u>
1. Select	III
2. Record	Iv&v
3. Examine	VI
4. Develop	VII
5. Define	IV, V&VI
6. Sell	VIII
7. Install	VII & VIII
8. Maintain	VIII

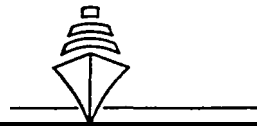
SECTION II of the course manual

This section deals with the first step of conducting a methods study; that is, selecting the work to be studied.

Pages 17-20 discuss two different ways to start an analysis. Cues/Indicators covers the questioning approach and the other addresses economic and technical considerations.

SECTION IV of the course manual

This section covers the recording of facts and analyzing the methods currently in use. The purpose of this section is to provide the participant with the tools to conduct proper operations analysis.



Page 21 is an introduction to Section IV and prepares the student for four commonly used tools for methods analysis.

In order to conduct an effective class on operations analysis, the following is recommended:

1. Review Operations Analysis form, Page 22, with the students. Work through it with a typical shipyard example, then give them another operation to review. Possible candidates for this would be ladder assemblies, longitudinal fabrication, web frame assemblies, etc.
2. Review the symbols and terms for Process Charting on Page 23. Use the booklet "Process Charts" as a reference or to expand your discussion on process chart methodology.
3. Review the panel assembly operation on Page 23, then instruct the attendees to fill in the correct symbols. Review their performance on this exercise using Page 23A, found at the back of this guidesheet. This procedure should help the attendees grasp the fundamentals of process charting. Pages 24-27 represent another charting example that the attendees can complete.
4. Another useful analytical tool is the linear responsibility chart (LRC). There is a reprint of an article on LRC by Don Barnes, the pilot workshop instructor. Use this section to train personnel on the use of LRC and with the blank form, have them perform an application in the yard.

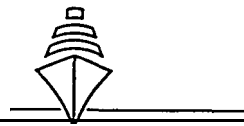
To broaden the exercises, assign the attendees an operation analysis in the yard. The attendees could then go out and use the newly learned techniques to analyze operations in the yard.

SECTION V of the course manual

This section covers recording and measuring the time it takes to perform an operation. Just a few techniques are discussed in this section. Measurement of a task can be done on a wide spectrum, from an educated guess to predetermined time systems (PTS). The level of measurement in industry today is closer to the educated guess method than the PTS method. The most useful and universally used measuring technique in use is work sampling.

You should develop a set of slides similar to the ones used in the workshop. Use these slides to simulate a work area for training students in the techniques.

The workshop material covers work sampling in depth. A follow-on exercise should be done by sending the students out into the yard to perform a work sampling study. This will probably be the most valuable exercise of the subsequent training.



SECTION VI of the course manual

This section covers examining the facts utilizing the laws of motion economy. Pages 64-66 cover the traditional principles of motion economy. Some people believe these laws are too "micro" in nature and don't apply to shipbuilding. This may be true in some areas, however, they definitely have their place. Pages 67-68 introduce three laws specifically developed for shipyards.

Pages 69-72 introduce a few motion economy devices. After covering this material, a tour of the yard should be taken to look for other such devices. Have the students also try and identify tasks that could use such devices.

SECTION VII of the course manual

The purpose of this section is to provide the attendee with documented, properly prepared case studies. It can be used to reinforce many of the techniques and fundamentals discussed in previous examples.

In addition, there is a section on shipyard layout principles (Page 89) which the participants should complete at their own pace. The material handling section (Page 75) also discusses the types of equipment used in shipyards along with a detailed utilization study of lift trucks.

You should review each case study in depth, not only in contents but also in format. To broaden the scope of this section, assign a case study to one person or groups of two or more participants. They can perform the studies and fully document the results. These results can expand this section and help improve productivity in your yard.

SECTION VIII of the course manual

One of the most important aspects of methods engineering is discussed in this section. In order for a method to be improved, people have to be sold on the idea. If this is ignored, a good idea could be a loser. The importance of getting people involved should be stressed to the students. If this is done, the solution will sell itself.

EQUIPMENT AND MATERIALS

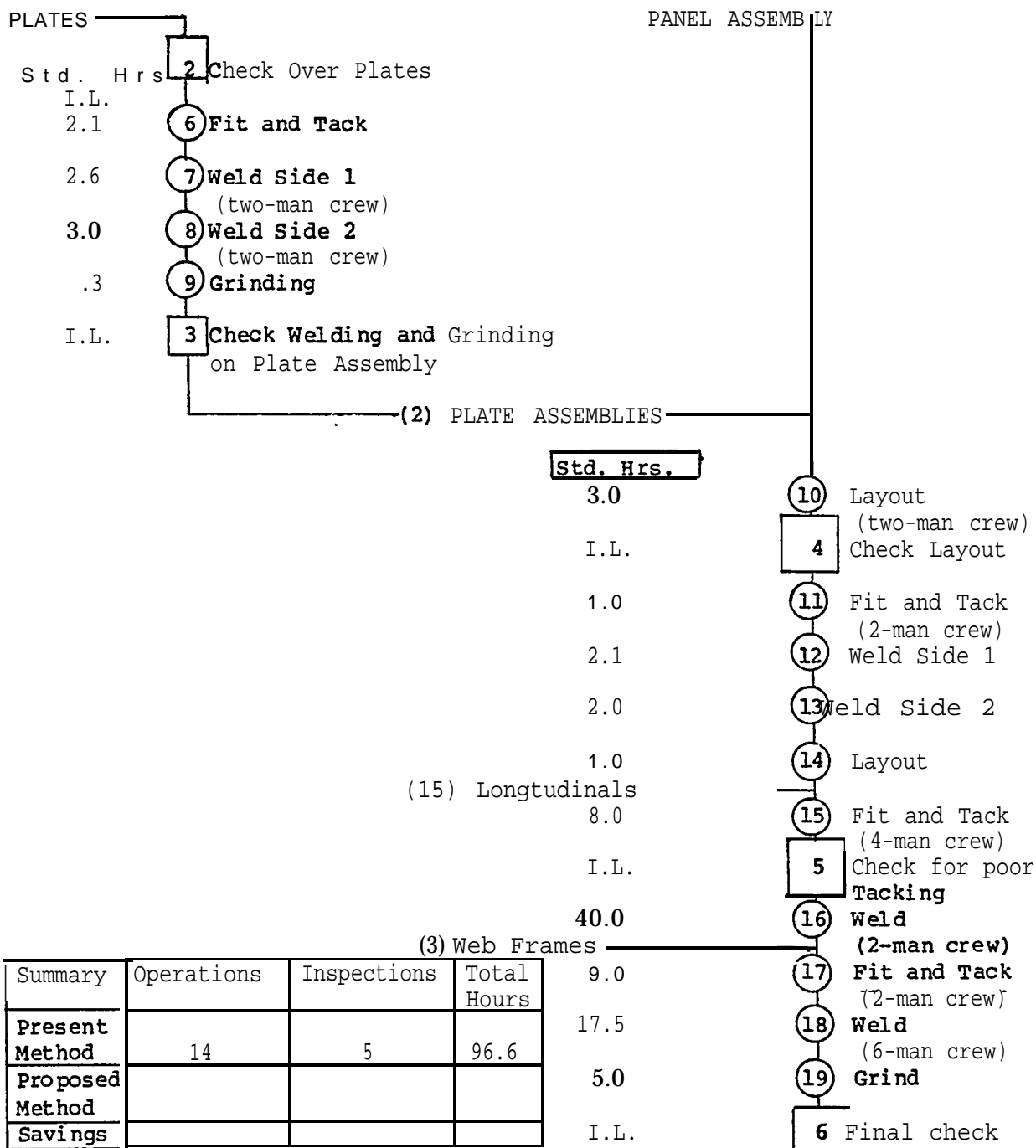
Necessary additional materials include:

- 1.. Extra carbon paper and blank sheets for the Shipyard Layout exercise in Section VI.
2. Duplicate forms and charts. NOTE: Before using the forms in your course manual, copy them in quantity for use by the attendees.



TYPICAL PANEL ASSEMBLY OPERATION

The operation process chart here indicates those activities for flat panel assemblies starting at the panel line.





INTRODUCTION

In order to stay in business in today's economy, we have to build and repair ships tomorrow with better productivity than we did yesterday.

The principles of methods improvement currently are in use in many industries throughout the world, but use is limited in U.S. shipyards. There is a need to improve and become more competitive. Being more competitive by improving manufacturing techniques will result in more jobs, better wages, job security, and many other benefits. This is the reason for promoting engineering techniques in U.S. shipyards.

During the course of this workshop we will cover a number of techniques that will help you in making a contribution towards improving your shipyard's position in the marketplace. Your participation and input will increase the value that is to be gained from the material that is to be presented.

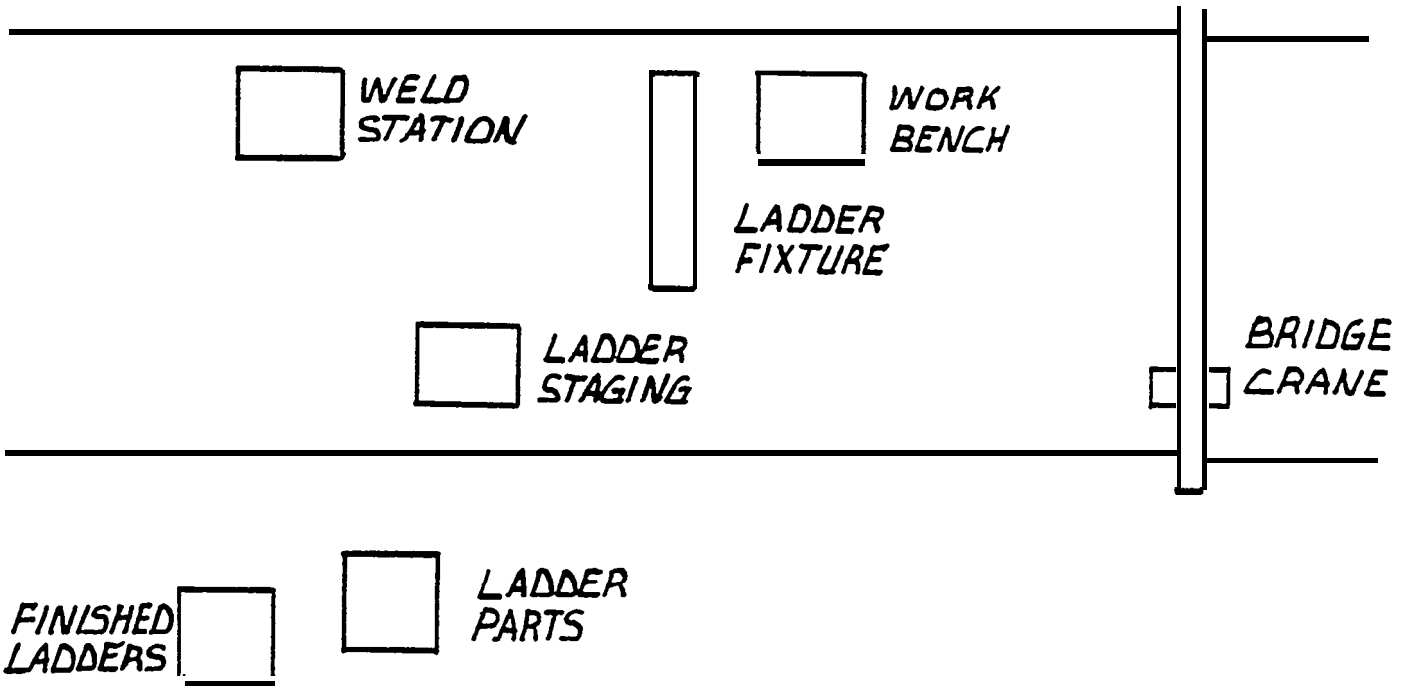
We will be discussing productivity and how to improve it, as well as improvement attitudes and the techniques used to promote and implement them. The major portion of this workshop will address the methods engineering aspect of methods improvement. We will cover each of the basic procedures and techniques in detail. Their use will be demonstrated in case studies.

The methods engineering discipline will provide the tools required to help generate the "questioning" attitude that is needed for change.

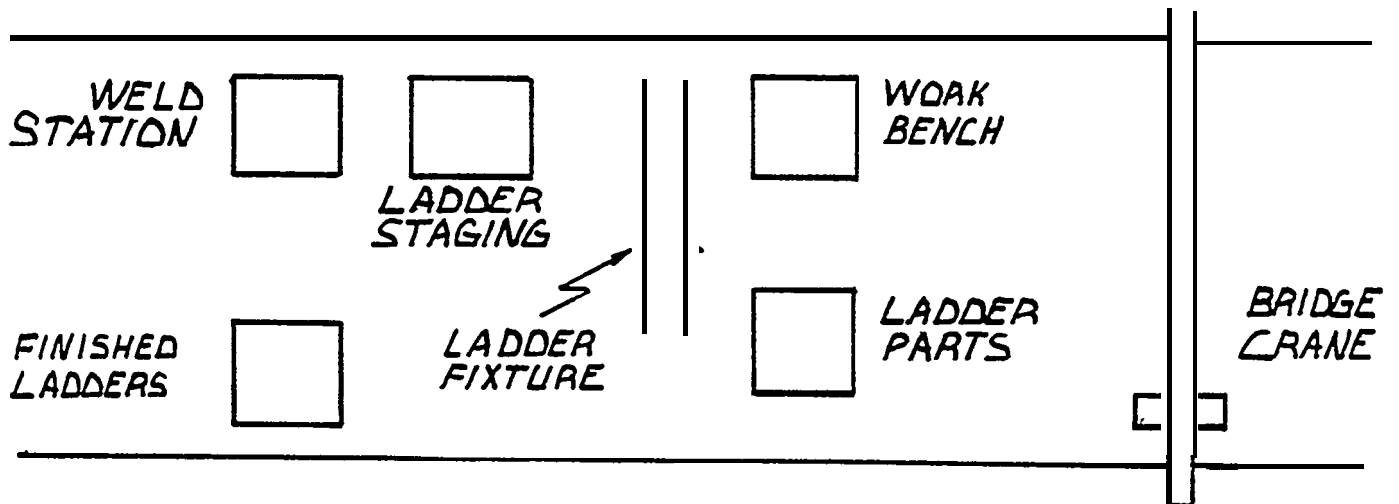
You can select just about any operation at random in a shipyard and improve it. For example, examine a typical assembly operation for steel ladders; the large number of motions spread over a long distance seems to indicate an inefficient layout. A closer look showed that relocation of parts and final assemblies had potential for improvement.

A sketch of the present and proposed layouts shows this improvement potential:

EXISTING LAYOUT



PROPOSED LAYOUT





INSTRUCTORS

DONALD W. BARNES - President, Barnes Management Training Services, Fort Lauderdale, Florida

Mr. Barnes has more than twenty-five years of experience as a training specialist and consultant in the fields of industrial and methods engineering. He is recognized as one of the leaders in work measurement and methods improvement training, and has lectured and taught at conferences and workshops throughout the United States, representing the American Management Association, the Institute of Industrial Engineers, and the MTM Association.

As a consultant, Mr. Barnes has served a variety of business organizations and industries including shipyards in California and Florida. He is a certified instructor of MTM- 1, 2, and 3 and is a member of the Board of Directors of the MTM Association. Mr. Barnes is also a Senior Member of IIE. He is the recipient of the Outstanding Industrial Engineer Award from the Miami, Florida chapter of IIE and the Fellows Award from the MTM Association.

JAMES RUECKER - Chief Manufacturing Engineer, National Steel and Shipbuilding Company, San Diego, California

Mr. Ruecker brings to the workshop more than fifteen years of industrial engineering experience with proven skills in methods engineering, engineered labor standards, facilities planning and development, and plant layout and material handling analysis.

As Chief Manufacturing Engineer at NASSCO, Mr. Ruecker has been instrumental in the improvement of shipyard assembly and manufacturing techniques to include:

- Development of engineered laker standard data for shipbuilding using predetermined time systems.
- Management of the development of the long-range facilities plan for expansion and reindustrialization of the NASSCO shipyard.
- Design and implementation of a methods engineering program including staff training and development.

Mr. Ruecker is a Senior Member of IIE. He has been certified in the use and training of predetermined time systems such as MOST, MTM-1, and MTM-4.



SHIPYARD INDUSTRIAL ENGINEERING

Key members of the maritime community recognized some time ago the value of applying the analytical and common-sense techniques of industrial engineering within U.S. shipyards. In order to raise the awareness of shipyard decision makers to the benefits of scientific management and to promote the use of an analytical approach to problem solving in shipbuilding, a forum was created for information exchange.

Under provisions of the Merchant Marine Act of 1970, the U.S. Maritime Administration (MARAD) established the National Shipbuilding Research Program (NSRP) to develop improved technical information and procedures for use in U.S. shipyards.

As the program evolved, direction was provided by the Ship Production Committee of the Society of Naval Architects and Marine Engineers (SNAME). This committee, along with the Bath Iron Works Corporation, proceeded to establish the proper direction to reduce the cost and time for ship construction.

In order to carry out these objectives, MARAD, Bath Iron Works, and the Institute of Industrial Engineers (IIE) held a three-day planning workshop with representatives from U.S. shipyards in February 1978. A direct result of the workshop was the formulation of the Shipyard Industrial Engineering Panel, SP-8 .

Since 1978 the panel has broadened its approach beyond new construction to include overhaul and repair operations.

Panel members presently represent Naval and Coast Guard commercial shipyards, the Maritime Administration, Naval Sea Systems Command, and the industrial engineering profession.

Panel-sponsored projects are funded jointly by the U.S. shipbuilding and repair industry, the U.S. Maritime Administration, and the U.S. Navy on a cost-shared basis.



Section I Productivity

What Is Productivity? 5

Audio-Visual Presentation: "Three Steps to Improved Productivity"





WHAT IS PRODUCTIVITY?

Productivity may be defined as follows:

"PRODUCTIVITY IS THE RATIO OF OUTPUT TO TOTAL INPUTS "

This definition applies in an enterprise, an industry, and an economy as a whole.

Put in simpler terms, productivity, in the sense in which the word is used here, is nothing more than the arithmetical ratio between the amount produced and the amount of any resources used in the course of production. These resources may be:

- Land
- Materials
- Plant, machines, and tools
- The services of people

Or, as is generally the case, a combination of all four.

We may find that the productivity of labor, land, materials, or machines in any industry or country has increased, but this bare fact does not in itself tell us anything about the reasons why it has increased. An increase in the productivity of labor, for example, may be due to better planning of the work on the part of the management or to the installation of new machinery. An increase in the productivity of materials may be due to greater skill on the part of workers, to improved designs, and so on.

- Productivity of Land

The productivity of land used for shipbuilding or repair may be said to have been increased if additional output can be met without increasing the acreage to support it. One such way to increase the productivity of land would be to utilize storage racks rather than spread the material out on the ground. Therefore, the productivity of that land, in the storage sense, has been increased.

- Productivity of Materials

If a skillful burner is able to cut eleven fitting saddles from a plate from which an unskillful burner can only cut ten, in the hands of the skillful burner the plate is used with 10 percent greater productivity.

- Productivity of Machines

If in the Machine Shop a machine tool has been producing forty pieces per day and through the use of improved cutting tools its output in the same time is increased to fifty pieces, the productivity of that machine has been increased by 25 percent.



Productivity of People

If a grit blaster has been cleaning thirty square-feet of steel per hour and an improved method of blasting has been implemented which will enable him to cover forty square-feet an hour, the productivity of that man has increased by 33 1/3 percent.

In each of these deliberately simple examples output--or production--has also increased, and in each case by exactly the same percentage as the productivity. But an increase in production does not by itself indicate an increase in productivity. If the input of resources goes up in direct proportion to the increase in output, the productivity will stay the same. And if input increases by a greater percentage than output, higher production will be achieved at the expense of a reduction in productivity.

In short, higher productivity means that more is produced with the same expenditure of resources, i.e., at the same cost in terms of land, material, machine-time, or labor; or alternatively that the same amount is produced at less cost in terms of land, materials, machine-time, or labor used up, thus releasing some of these resources for the production of other things.

U.S. Shipbuilding Industries Need to Increase Productivity

In a short five-year period of time during World War II, the U.S. shipbuilding industry achieved unprecedented levels of productivity as it constructed, repaired, and maintained the largest and most powerful naval and merchant fleet the world has ever known. This remarkable feat was accomplished through a totally cooperative effort among shipbuilders, ship designers, suppliers, and the U.S. Government acting as an integrated team. Five principal factors made this achievement possible: first, a national commitment to get the job done; second, recognition and support of the shipbuilding industry as a national asset; third, a dependable workload; fourth, extensive standardization of ship and ship component designs; and fifth, highly effective organization of the ship construction process.

After the war, the United States found itself with a tremendous surplus of both naval and merchant ships and so new ship orders dropped off to virtually nothing. Without the opportunity to build ships on a dependable basis, the U.S. shipbuilding industry quickly lost the highly effective volume production methods it had built up during the war.

When the worldwide demand for commercial ships once again started accelerating appreciably, our foreign competitors with their significantly lower labor rates, were in a position to capture a continually increasing share of the market. As their backlog of orders grew, foreign shipbuilders adopted and perfected the very shipbuilding methods which had been developed by the U.S. shipbuilding industry during World War II.

This sequence of initially lower foreign labor rates, followed by aggressive adoption of improved shipbuilding technology, coupled with enlightened foreign



governmental maritime policies, has led to progressively increasing foreign domination of the shrinking worldwide commercial shipbuilding market and the concomitant decline of the U.S. industry's competitiveness in the international arena. Also contributing to the current U.S. maritime situation, have been the lack of a viable U.S. maritime policy and late start on the part of the U.S. yards to invest in improved facilities and methods to keep pace with the times.

Now the U.S. shipbuilding industry is faced with the challenge of rebuilding, maintaining the nation's seapower at an acceptable level, and recapturing a greater share of the world's commercial market in order to survive and prosper once again.

Instilling the Methods Improvement Attitude

Many people have been misled into thinking of productivity exclusively as the productivity of labor, mainly because labor productivity usually forms the basis for published statistics on the subject. In this workshop the problem of raising productivity will be treated as one making the best possible use of all the available resources, and attention will constantly be drawn to cases where the productivity of materials or plants is increased.

The main responsibility for raising productivity rests with management. Only management can introduce and create a favorable climate for a productivity program and obtain the cooperation of the workers which is essential for real success, though this requires the good will of the workers too.

One of the greatest difficulties in obtaining the cooperation of the workers is the fear that raising productivity will lead to unemployment. Workers fear that they will work themselves out of their jobs. This fear is greater when unemployment already exists and workers who lose their jobs find it hard to get others.

Even with written guarantees, steps taken to raise productivity will probably meet with resistance. This resistance can generally be reduced to a minimum if everybody concerned understands the nature of and reason for each step taken and has some say in its implementation.

To implement a successful program, the first step is to train in the proper use of tools and techniques of methods engineering; then promote the program by making the organization aware of the need for improvement and of the benefits that can be achieved.



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THE METHODS IMPROVEMENT ATTITUDE

Throughout this program you will hear the subject of methods improvement mentioned a great deal. The method used to perform any operation is of basic importance since the time required to perform the method will determine the amount of production. The method will also determine the quality of the finished product and the overall cost of the operation.

Since high productivity keeps a company competitive, methods improvement must constantly be considered. In most industries today, special departments (i. e., industrial engineering, time study, work measurement or methods) are employed, and it is their major task to see that the most effective working methods are being used.

It is only reasonable to expect that all production supervisors want to have a good understanding of what effective working methods are and how to recognize them. Effective methods contribute to higher profits and a profitable company is in a better position to increase wages or to offer greater benefits or opportunities than a nonprofitable company.

Methods improvement is largely a matter of systematic application of sound, practical common sense. One may say that it is common sense systematically applied. There are a large number of highly specialized methods improvement techniques available today. A thorough description of each technique applicable to shipbuilding will be covered in this course; however, at this time we will confine ourselves to the most generally applied principles of methods improvement.

The most important single asset to success with methods improvement is mental attitude. A desire to ask questions and to be "downright curious" often leads to a sizable methods improvement. A healthy curiosity is sometimes far more valuable in connection with methods study than a thorough knowledge of the job. When a person has achieved a good working knowledge of the job, there is a tendency to feel that the best methods have been attained and that additional methods work is not necessary. This is not true. If the attitude that "no improvement can be made" is prevalent, nobody will try to make any improvement. Thus, the possibility of a better method may die on the spot.

A slogan used by many industrial engineers is: "With sufficient study, any method can be improved." of course, practical limitations prevent a method from being improved to the point of perfection. From a theoretical standpoint, however, methods improvement can never be complete as long as the operation itself exists. It is better to call a methods improvement "the best method yet devised."

Later, you will learn how to apply various techniques for improving methods. You will also learn about the Laws of Motion Economy and how they work.



The Laws of Motion Economy were developed by Frank and Lillian Gilbreth, pioneers in the field of scientific management. Frank Gilbreth became interested in improving methods when, on his first day as a bricklayer's apprentice, he discovered a large variety of different methods used for the simple task of laying a brick.

If one of the oldest trades known to man could be improved, then, with sufficient study, any method could be improved. As long as ingenuity and fresh viewpoints are brought into play, methods improvement can theoretically continue ad infinitum. It is important for persons to have the attitude that methods improvement is a continuing practice. It will not only make it far more likely that they find a better way of doing the job, but their optimism can change the attitude of others as well.

It has been noted several times that methods improvements are a continuing process so long as the operation exists. It should be noted that the ultimate methods improvement is to completely eliminate an operation, piece of material, use of land, whatever. An example of this is "landing" material on a "block" before erection; thus eliminating the material handling operation of lifting that material with a crane. Great care should always be exercised to ensure that you have increased the overall productivity and not just reduced effort in one area while increasing it in another area. The ultimate snafu is to have reduced one man-day of effort in one area while increasing the job to two man-days of effort in another area.



METHODS ENGINEERING TECHNIQUES

Methods engineering embraces several techniques but, in particular, method study and work measurement.

Method study is the systematic recording and critical examination of existing and proposed ways of doing work, as a means of developing and applying easier and more effective methods and reducing costs.

Work measurement is the application of technique designed to establish the time for a qualified worker to carry out a specified job at a defined level of performance.

Method study and work measurement are, therefore, closely linked. Method study is concerned with the reduction of work content of a job or operation, while work measurement is mostly concerned with the investigation and reduction of any ineffective time and with the subsequent establishment of time standards for the operation when carried out in the improved fashion, as determined by method study. The relationship of method study to work measurement is shown in a following diagram. (See page 12.)

Method study will be dealt with in detail in the remainder of this workshop. The subject of work measurement will be discussed here very briefly so that you gain a general understanding of the subject.

Work measurement, as the name suggests, provides management with a means of measuring the time taken in the performance of an operation or a series of operations in such a way that ineffective time is shown up and can be separated from effective time. In this way its existence, nature, and extent become known where previously they were concealed within the total. Once the existence of ineffective time has been revealed and the reasons for it tracked down, steps can usually be taken to reduce it.

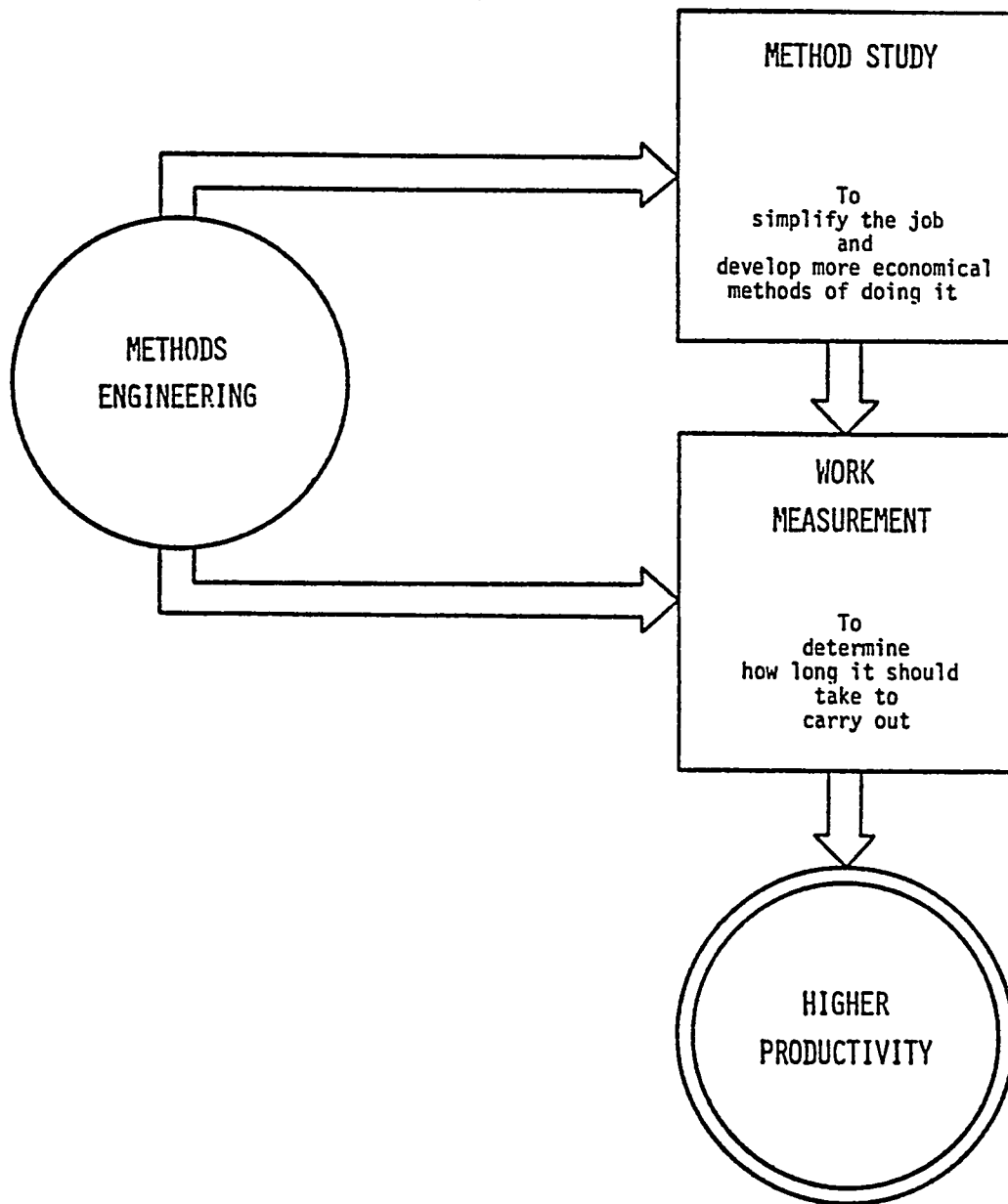
Work measurement has another role to play. Not only can it reveal the existence of ineffective time; it can also be used to set standard time for carrying out the work so that, if any ineffective time does creep in later, it will immediately be shown up as an excess, over the standard time and will thus be brought to the attention of management.

Work measurement is more likely to show up the management itself rather than the poor behavior of workers. Because of this, it is apt to meet with far greater resistance than method study. Nevertheless, if the efficient operation of the yard as a whole is being sought, the application of work measurement, properly carried out, is one of the best means of achieving it.



The basic procedure of work measurement is as follows:

- Select the work to be studied.
- Record all the relevant data relating to the circumstances in which the work is being done, the methods and the elements of activity in them.
- Examine the recorded data and the detailed breakdown critically to ensure that the most effective method and motions are being used.
- Measure the quantity of work involved in each element, in terms of time, using the appropriate work measurement techniques.
- Compile the standard time for operation, which should include time allowance for personal, fatigue, and delays.
- Define precisely the series of activities and method of operation for which the time has been compiled.





METHODS ENGINEERING TERMS AND DEFINITIONS

- _____. A delay which is under the control and responsibility of the worker.
- _____. An element whose work content and normal time do not vary significantly although some other aspect of the job changes.
- _____. A listing of work elements with individual descriptions and/or calculations for each; the separation of a work cycle.
- _____. The amount of work that management expects daily from an employee. Expected attainment.
- _____. An adjustment to normal time to compensate for loss of production time due to the operator resting.
- _____. A graphic, symbolic representation of work performed on a product as it passes through some or all of the stages of production.
- _____. Work that is not readily chargeable to or identifiable with a specific product or service.
- _____. The design, improvement, and installation of integrated systems of people, materials, and equipment, drawing upon socialized knowledge and skill to specify, predict, and evaluate the results to be obtained from such systems.
- _____. An adjustment to standard time to compensate for idle machine time when the work cycles of the operator and two or more machines do not coincide.
- _____. A summary of essential activities of a job abstracted from job analysis and used in the classification of a job.
- _____. A plot of productive output as a function of time where the time per unit will usually decrease as the worker becomes proficient in work performance.
- _____. Average daywork performance under conditions of little supervisory control. Often taken to be 83 1/2% of normal task.
- _____. A collection of analysis techniques that focus attention on improving the effectiveness of people and machines, including the design of controls. "Common sense systematically applied."
- _____. Use of the basic principles of the method in which body motions are performed to simplify and reduce work content.



_____. A graphical set of lines or curves representing equations arranged so that a solution can be obtained by connecting points representative of independent variables.

_____. The manual working pace that requires normal effort to perform.

_____. A study that encompasses all procedures concerning design, operation purpose, inspection requirements, materials, material handling, setup, tools, working conditions, and methods.

_____. A graphic and symbolic representation of the complete sequence of producing a product showing the operations and inspections performed.

_____. The planning of plant structure, service facilities, and production facilities.

_____. "Management based on measurement plus control. " F. W. Taylor

_____. A formula for determining the normal time or standard time of a task as a function of one or more variables in the task.

_____. A delay which is outside the control or responsibility of the worker.

_____. A work measurement technique consisting of intermittent, instantaneous observations of work activity or delays.

_____. Improvement in work methods initiated and developed on the job as a result of methods training and/or incentives.



OBJECTIVES OF METHOD STUDY

Method study is the systematic recording and critical examination of existing and proposed ways of doing work, as a means of developing and applying easier and more effective methods and reducing costs.

The objectives of method study are:

- The improvement of processes and procedures
- The improvement of yard, shop, and workplace layout and of the design of plant and equipment
- Economy in human effort and the reduction of unnecessary fatigue
- Improvement in the use of materials, machines, and manpower
- The development of a better physical working environment.

There are a number of method study techniques suitable for tackling problems on all scales from the layout of a complete shipyard to the smallest movement of workers on a repetitive job. In every case, however, the method of procedure is basically the same and must be carefully followed. There are no shortcuts.

Work Measurement and Methods

12

Z94.12

This aspect of industrial engineering — WORK MEASUREMENT AND METHODS — is historically *the* basic field. Taylor's original interest was an attempt at answering the fundamental question: "WHAT IS A FAIR DAY'S WORK?" (See INTRODUCTION, *Industrial Engineering Field*.) Although a good part of Taylor's work was associated with stopwatch studies, it remained for the Gilbreths to search for THE ONE BEST WAY. For many years there was a schism, then finally a combination of Motion and Time Study, which dominated the IE field. It was from these pioneers that the field was expanded into the psychology of the worker as well as the physiology of her/his performance, into the measurement of the task as well as the methods of performing it.

The TERMINOLOGY in this section contains several hundreds of terms of interest to the worker as well as the manager, and should prove of value not only in measuring performance but also in paying for it. Although the terms in this section represent a revision of the 1972 Z94.12

edition, it would not be amiss to point out that Dr. Williams' earliest contributions appear in the INDUSTRIAL ENGINEERING TERMINOLOGY, which appeared in the JOURNAL OF INDUSTRIAL ENGINEERING, (AIIE, November - December, 1965).

The present subcommittee consisted of the following:

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Mitchell Fein Inc.
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Gottlieb and Associates
Dr. Charles M. Overby, P.E.
Ohio University
Dr. Robert L. Williams, Chairman
Professor and Chairman, Industrial and Systems Engineering, Ohio University

abnormal reading, See abnormal time.

abnormal time, A time value which is outside of statistical or policy variance limits. Syn: abnormal reading.

accumulative timing, A multiple (usually three) stopwatch technique for time study in which a mechanical linkage pressed at successive cycle breakpoints instantaneously stops, starts, and resets the individual watches so that, respectively, they may be: read for recording the latest element time, timing the element currently being observed, and ready to time the next element.

activity sampling, See work sampling.

actual hours, See actual time.

actual time, The unadjusted time for the accomplishment of a defined task or task element as obtained by a timing device. Syn: observed time.

allowance, (1) Work measurement a time value or percentage of time by which the normal time is increased, or the amount of non-productive time applied, to compensate for justifiable causes or policy requirements which necessitate performance time not directly measured for each element or task. Usually includes: irregular elements, incentive opportunity on machine controlled time, minor unavoidable delays, rest time to overcome fatigue, and time for personal needs. (2) Dimensional: the minimum clearance or maximum interference distance between two interpenetrated objects. (See training allowance.)

allowed hours, See standard hour, allowed time.

allowed time, A normal time value increased by an appropriate allowance(s). (See standard time.)

assignable cause, A source of variation in a process which can be isolated, especially when its significantly larger magnitude or different origin readily distinguishes it from random causes of variation.

auxiliary process time, The time required for essential supplementary process operations which assure the continuity and completion of the principal process operations. Such auxiliary operations as deburring, straightening, cleaning, and finishing usually result in relatively minor changes in the appearance of physical characteristics of the workpiece in comparison with the effects due to such principal operations as cutting, forming, welding, casting, and assembly.

available machine time, The portion of a time cycle during which a machine could be performing useful work.

available process time, The portion of a time cycle during which a process agent or system could be acting usefully on the product.

average cycle time, (1) The sum of observed or actual work times, excluding abnormal times, divided by the number of such cycle observations. (2) The sum of the average element times. (See average element time.)

average element time, The sum of a series of observed or actual element times, excluding abnormal times, divided by the number of such element observations. (See average cycle time.)

average time, See average cycle time, average element time.

avoidable delay, A time delay not allowed in standard time calculations because it is unnecessary and is due to factors under worker control and responsibility.

balance, (1) The act of distributing the work elements between the two hands performing an operation or between the different operations in a process to achieve essentially equal performance times among them. (2) The state of approximately equal working time distribution among the various components of an operation or process, e.g., the stations on an assembly line.

balanced motion pattern, (1) The sequence of concurrent arm and hand movements over symmetrical paths that produce approximately equal momentum between the arms in directions which facilitate muscular equilibrium. (2) A series of movements with both hands involving negligible delay on idle time for either hand while the other is working.

balancing delay, (1) The idle time of one hand in an operation due to imperfect balancing. (2) The idle time of one or more operations in a series due to imperfect balancing (See balance.) Syn: balance delay.

ballistic movement, A motion of a body extremity with relatively simple muscle action that is rapid, smooth, and flowing from start to finish. Such action results when a antagonistic muscle group causes motion in the intended direction to attain a peak force and velocity, which retards to zero as an antagonistic muscle group changes the direction or causes motion to cease. This sequential muscle action contrasts with that producing nonballistic motion, in which the antagonistic and antagonistic muscle groups act concurrently to precisely control the force and velocity of movement. Historically, the term is associated with the similarity of the motion plot to projectile trajectory plots.

bank, See float.

basic division of work, See therblig.

basic element, See elemental motion.

basic motion, A human motion closely related to primary physiological and/or bio-mechanical performance capabilities of the body or its members (e.g., a therblig or other standard motion defined within a predetermined time system). Compare: elemental motion.

benchmark, A standard of measurement with enough characteristics common to the individual units of a population to facilitate economical comparison of attributes for units selected from a sample. Benchmarks may be used for job evaluation, performance rating, establishing operational standards, standard data development, cost estimating, and other purposes. (See benchmark job, key job.)

benchmark job, A job with enough characteristics common to other jobs, judged acceptable as a gauge for those other jobs without their direct measurement for time standards, job evaluations, or other purposes. (See benchmark.)

breakpoint, A point in a work cycle readily distinguished by sight and/or sound which is selected as the boundary between two elements for time recording or element definition in motion study. Syn: reading point; endpoint.

building block, An approach used in standard data development of creating fixed groups or modules of work elements which may be added together to obtain time values for elements and entire operations.

- camera study, See micromotion study, memomotion study.
- changeover time, The time required to modify or replace an existing facility or workplace, usually including both tear-down time for the existing condition and setup of the new condition. (See setup, teardown.)
- check study, A partial or complete review of a job or operation to evaluate the validity of a standard time.
- chronocyclegraph technique, A modification of the cyclegraph technique to permit the computation of motion velocities and accelerations from the spacing of light signals on the film whose shapes indicate the direction of movement, produced by pulsing the lights on and off at regular time intervals. (See cyclegraph technique.)
- chronological study, A detailed sitxty and recording of a sequence of events in the order of occurrences. (See production study.)
- coding, (1) Translation of a data processing machine program from descriptive, symbolic, or diagram form into machine language (code) or into an explicit symbolic language that may retranslated directly into machine language by means of an assembly program or compiler. (2) Referring numbers to a convenient origin and/or scale for ease of computation. (3) Assigning a numerical and/or alphabetical symbol or group of symbols to a class or variable to achieve consistent identification, location, or interpretation. A desirable property of such symbology is the mnemonic, or memory-jogging characteristic to promote efficient association of the code meaning.
- combined motions, Two or more nonconsecutive elemental motions performed during the same time interval by the same body member.
- combined work, (1) The production of a person working with one or more machines in which the output is controlled by the operator. In calculating a standard, the machine portion of the work cycle is not taken into account. (2) The total accomplishment of a group of workers.
- consistency, (1) The absence of noticeable or significant variation in behavioral or numerical data as, for example, in the work pace or method used by a worker. (2) Uniformity or agreement, within stated limits, between repetitive occurrences of an event or a numerical value.
- constant element, A job or task element which occurs without significant variation in work content and/or performance time. May be used to describe elements within a given operation or elements common to different operations.
- continuous method, See continuous timing.
- continuous reading, See continuous timing.
- continuous timing, A stopwatch technique in which the watch runs continuously throughout the study and readings are made of the cumulative time at the end of each element. Individual element times are then obtained by subtraction. Syn: continuous method, continuous reading.
- control system, A system that has as its primary function the collection and analysis of feedback from a given set of functions for the purpose of controlling the functions. Control may be implemented by monitoring and/or systematically modifying parameters or policies used in those functions, or by preparing control reports that initiate useful action with respect to significant deviations and exceptions.
- coverage, actual, The number of jobs, the number of personnel, or the total hours which are covered by standards during the reporting period. Commonly expressed as a percentage of the total number of jobs, personnel, or hours. Syn: standard coverage.
- coverage, potential, An estimate of the number of jobs, the number of personnel, or the total hours which can be covered by time standards during the reporting period. Commonly expressed as a percentage of the total number of jobs, personnel, or hours.
- coverage, standard, See actual coverage.
- cycle, The complete sequence of activities, operations, and machine or process times required to complete one segment, unit, or batch of work. (See motion cycle, work cycle.)
- cycle timing, Timing a complete work cycle as a single time value rather than timing the individual elements of the cycle. (See differential timing.)
- cyclegram, Similar to cyclegraph except that the film being exposed is moved slowly to one side so that retraced motions are shown side by side on the film rather than superimposed on earlier motions.
- cyclegraph, The pattern developed by the cyclegraph technique. (See cyclegraph technique.)
- cyclegraph technique, The use of small fights on the hands or other body members to indicate their motion patterns. The lights are recorded by a still camera in a darkened room with an exposure time equal to at least one motion cycle.
- cyclic element An element of an operation or process that occurs in every cycle of the operation or process.
- cyclic timing, See cycle timing.
- daywork, Work for which pay is based on time as contrasted to pay based on performance.
- decimal-hour stopwatch, A timing device with two hands whose movement may be started, stopped, or reset to zero by depressing control buttons on the perimeter of the watch case. A small dial is calibrated in hundredths of an hour and a large dial is calibrated in ten-thousandths of an hour. Thus, the time interval may be read in decimal hours to four decimal places.
- decimal-minute stopwatch, A timing device with two hands whose movement may be started, stopped, or reset to zero by depressing control buttons on the perimeter of the watch case. A small dial is calibrated in whole minutes and a large dial is calibrated in hundredths of a minute. Thus, the time interval may be read in decimal minutes to two decimal places.
- delay, A pause or interruption in the scheduled work activity of the human, machine, or product flow. (See avoidable delay, unavoidable delay, inherent delay.) Syn: interruption, stoppage.
- delay allowance, (1) A time increment to allow for contingencies and minor delays beyond the control of the operator. May be included in a time standard as a percentage or as non-productive time. (2) A separate credit (in time or money) to compensate the operator on incentive for a specific instance of delay not covered by the piece rate or standard. (See unavoidable delay allowance.)

delay time, A period during which an employee is idle due to breakdown of equipment, lack of tools or materials, or any other factor beyond personal control. (See downtime, idle-time.)

diagnostic study, A brief investigation or cursory methods study of an operation, process, group, or individual to discover causes of operational difficulties or problems for which more detailed remedial studies may be feasible. An appropriate work measurement technique may be used to evaluate alternatives or to locate major areas requiring improvement. Syn: survey.

differentiat timing, The time study technique used to obtain the time value of an element of extremely short duration. It consists of: (1) obtaining cycle values, first including and then excluding the element for which the time is required, and obtaining the required element time by subtraction: (2) timing the element by combining it with preceding and/or following elements in successive cycles and then obtaining the time for the short element by subtraction.

direct labor, (1) Work which is readily chargeable to or identifiable with a specific product. (2) Work performed on a product or service that advances the product or service towards its completion or objectives.

direct labor standard, A standard time set on a direct labor operation. (See direct labor.)

discontinuous timing, See repetitive timing.

division of labor, The separation of jobs or tasks into less complex jobs or tasks usually to allow use of workers possessing less skill than that required by the overall job or task, or to make use of special skills. Syn: division of work.

downgrade, (1) The lowering of a particular job in scope, authority, responsibility, degree of difficulty, etc., with a possible reduction in wage or salary. (2) Dilution of skills required for the task. (See division of labor.)

downtime, A period of time during which an operation is halted due to the lack of materials, a machinery breakdown, or the like. (See downtime, Applied Mathematics, Applied Psychology. Production Planning and Control.)

drop delivery, (1) The movement of a component or object to some location where it is merely let go rather than being placed where it is to go. (2) Provisions in a workplace for disposal of objects by dropping.

earned hours, The time in standard hours credited to a worker or a group of workers as a result of their completion of a given task or group of tasks; usually calculated by summing the multiproduct of applicable standard times and the completed work units.

effectiveness, (1) The ratio of earned hours to actual hours spent on prescribed tasks. When earned hours equal actual hours, the effectiveness equals 100%. (2) The ratio of standard. estimated, or budgeted performance to actual performance expressed as a percentage. (3) The performance or output received from an approach or program. Ideally it is a quantitative measure which can be used to evaluate the level of performance in relation to some standard, set of criteria, or end objective. (See efficiency, labor.)

efficiency, labor, (1) The ratio of standard performance time to actual performance time, usually expressed as a percentage. (2) The ratio of actual performance numbers (e.g., the number of pieces) to standard performance numbers, usually expressed as a percentage. (See productivity.)

effort, The apparent physical and mental exertion exhibited by the worker while performing a segment of work.

effort controlled cycle, See manually controlled work.

effort rating, See performance rating.

elapsed time, (1) The actual time taken by a producing worker or machine to complete a task, an operation, or an element of an operation. (2) The total time interval from the beginning to the end of a time study. (See actual time.)

element, A subdivision of the work cycle composed of one or a sequence of several basic motions and/or machine or process activities which is distinct, describable, and measurable. (See manual element, machine-controlled time.)

element breakdown, (1) The separation of a work cycle into two or more elements. (2) A listing of work elements with individual descriptions and/or calculations for each.

element time, The time to perform a given element. May refer to the observed (raw), average, selected, normal or standard time.

elemental motion, individual manual motions or simple motion combinations used to describe the sensory-motor activity in an operation. Generally refers to the more basic and elementary therbligs. An attempt often is made to define these precisely with associated time values. Typical elemental motions are: reach, move, assemble, pre-position, turn.

elemental standard data, (1) Standard data. (2) A time value of an individual element in a standard data system.

endpoint, See breakpoint.

engineered performance standard, See standard time.

engineered standard, See standard time.

engineered time standard, See standard time.

ergonomics, The study of work tasks with emphasis on reducing to a practical minimum the physiological cost of doing the work. (See work design, methods engineering motion analysis, motion economy.)

ergonometrics, See ergonomics, work measurement.

estimated time, An element or operation time that has been predicted on the basis of such information as may be available without detailed study.

excess work allowance, An allowance to compensate for work required to be performed on an operation or job in addition to that specified in the standard method. Sometimes applied as a separate grant of time or as a grant of money in a piece-work system. (See allowance.)

expected attainment, See fair day's work.

expected work pace, (1) The work pace necessary for an operator to maintain in order to achieve a specified level of earnings under an incentive system. (2) The work pace required to meet non-incentive production standards.

external element, See external work.

external work, Any element of an operation which must be

- performed by the operator while the machine or process is not in operation and which results in a loss of potential machine or process operating time. The term "external" implies that the element occurs outside the machine or process cycle.
- fair day's work, The amount of work which is expected daily from an employee. May be established solely by management or through mutual agreement. May or may not be established through the use of various measurement techniques. (See normal performance.) Syn: expected attainment.
- fatigue, A psychological and physiological process that reduces the performance capacity and motivation of humans subjected to excessive or repeated work stresses.
- fatigue allowance, Time included in the production standard to allow for rest to overcome the effects of fatigue. May be applied either as a percentage of the leveled, normal, or adjusted time or as a stated number of nonproductive minutes per hour. (See allowance, standard time.)
- film analysis, A systematic, detailed analysis of work from a motion picture film. Usually related to micromotion or memomotion study. (See micromotion study, memomotion study.)
- film analysis chart, For recording a film analysis. Generally records each successive elemental motion, element, or operation, the beginning and ending dock time (if a clock is included in the picture) or frame number, and its descriptive symbol. (See simo chart, therblig chart.) Syn: film analysis record.
- film analysis record, See film analysis chart.
- films, rating, Motion picture films containing a consistent or random sequence of work scenes being done at varying performance levels, used to train work measurement analysts in identifying different performance levels. May also be used to attempt to standardize the concept of normal performance, such as in card dealing, walking, or typical shop operations.
- first piece time, The allowed time to produce the first piece in an order of several pieces. Intended to compensate for delays resulting from unfamiliarity with the work method, or for extra first piece work such as setup.
- fixture, A device used to position and hold materials which are being worked upon or assembled.
- float, (1) The amount of material in a system or process, at a given point in time, that is not being directly employed or worked upon. (2) The total cushion or slack in a network planning system. Syn: bank.
- flow analysis, Detailed examination of the progressive travel, either of personnel or material, from place to place and/or from operation to operation.
- flowchart, Tabular material, standardized symbols, and explanations depicting the predetermined route of either personnel or material, from place to place and/or from operation to operation in the manufacturing or processing sequence of events.
- flow diagram, A representation of the location of activities or operations and the flow of materials between activities on a pictorial layout of a process. Usually used with a flow process chart.
- flow line, (1) The direction taken either by personnel or material as they progress through the manufacturing or processing sequence of events. (2) The path along which personnel or material travel in progressing through the plant. Syn: line of flow.
- flow path, The route taken and/or space occupied by the personnel, material, subassembly, or assembly as these progress through the manufacturing process.
- flow process chart, A graphic, symbolic representation of the work performed on to be performed on a product as it passes through some or all of the stages of a process. Typically, the information included in the chart is quantity, distance moved, type of work done (by symbol with explanation), and equipment used. Work times may also be included. Flow process chart symbols generally used are:
- ASME*
Standard
- als, operation: a subdivision of a process that changes or modifies a part, material or product, and is done essentially at one workplace location.
- ical A specialized application for paperwork uses two standard symbols:
- techn creation of a record or set of papers
- plete addition of information to a record or set of papers
- very c
- fully transportation (move): change in location of a person, part, material, or product from one workplace to another.
- inspection: comparison of observed quality or quantity of product with a quality or quantity standard.
- storage: keeping a product, material, or part protected against unauthorized removal.
- delay: an event which occurs when an object or person waits for the next planned action.
- combined activity: adjustment during testing, e.g., would combine the separate operation and inspection symbols.
- "See ASME Standard 101
- Syn: flow chart, production process chart, product analysis chart.
- foreign element, An element with a random, usually unpredictable, frequency of occurrence, not part of a normal method.
- form process chart, A graphic, symbolic representation of the process flow of paperwork forms. Similar to a flow process chart except that the item of interest is one or more forms. A form process chart may show organizations, operations, movements, temporary and controlled storages, inspection or verification, disposal of all forms charted, as well as the source and type of information transmitted between forms. Flow process chart symbols may be adapted to reflect the form processing activity. Syn: information process analysis chart, functional forms analysis, forms analysis chart.
- frame counter, A mechanical counter which can be used to

- determine the number of frames that have passed a predetermined point in a motion picture. The frame counter may be attached to any device for showing or viewing motion pictures.
- frequency, (1) The number of times a specified value occurs within a sample of several measurements of the same dimension or characteristics on several similar items. (2) In work measurement, the number of times an element occurs during an operation cycle.
- fumble, An unintentional human activity referred to as a sensory-motor error that may or may not be avoidable depending upon the working environment or the skill of the operator.
- gang chart, See multiple activity process chart.
- Gantt chart, A graphic representation on a time scale of the current relationship between actual and planned performance. (See Production Planning and Control.)
- Gilbreth basic element, See therblig.
- gravity feed, The principle of using the force of gravity to convey materials from one location to another by having them slide or roll downward and laterally.
- hand time, The time required to perform a manual element. (See manual element.) Syn: manual time.
- handling time, The time required to move parts or materials to or from an operation or work area.
- high task, Performance of an average experienced operator working at an efficient pace, over an eight-hour day under incentive conditions, without undue or cumulative fatigue. Often stated as a percentage above normal performance. (See normal effort, low task.) Syn: incentive pace.
- historical time, See standard time, statistical.
- human engineering, See human factors engineering.
- human factors engineering, A merging of those branches of engineering and the behavioral sciences which concern themselves principally with the human component in the design and operation of human-machine systems. Based on a fundamental knowledge and study of human physical and mental abilities and emotional characteristics.
- idle machine time, See machine idle time.
- idle time, Time during which a worker is not working. (See avoidable delays, unavoidable delays, waiting time.)
- incentive pace, See high task.
- incentive operators, (1) Employees whose pay is determined all or in part by the quantity and/or quality of output. (2) Employees working under a wage incentive plan.
- Incidental element, See irregular element.
- indirect labor, Labor which does not add to the value of a product but which must be performed to support its manufacture. May not be readily identifiable with a specific product or service. (See indirect labor standard.)
- indirect labor standard, (1) An established standard of time for labor performed while rendering services necessary to production, the cost of which cannot be assessed against any part, product, or group of parts or products accurately or without undue effort and expense. (2) A standard time for indirect labor. (See indirect labor, standard time.)
- industrial engineer, A person qualified to practice industrial engineering as defined by the Institute of Industrial Engineers.
- industrial engineering, Concerned with the design, improvement, and installation of integrated systems of people, materials, equipment, and energy. It draws upon specialized knowledge and skills in the mathematical, physical, and social sciences together with the principles and methods of engineering analysis and design, to specify, predict, and evaluate the results to be obtained from such systems. (Official definition of the Institute of Industrial Engineers.)
- inherent delay, See delay time.
- instruction card or sheet, A written description provided to a worker which states the standard method or standard practice to be used.
- interference allowance, An allowance to compensate for interference time. (See interference time.)
- interference time, Idle machine time resulting from the inability of a machine operator, when assigned to two or more semi-automatic machines, to serve one or more of them when they require service. (See machine interference.)
- intermittent element, See irregular element, regular element.
- internal element, See internal work.
- internal work, Manual work performed by an operator while the machine or process is operating automatically. Syn: fill up work, inside work.
- irregular element, An element which occurs randomly and cannot be statistically determined.
- Jig, (1) A mechanical device used to guide a cutting tool along a predetermined path when in contact with the material or workpiece supported in the device. (2) A device used to hold parts in position (e.g., welding jig, airframe jig).
- job, (1) The combination of tasks, duties, and responsibilities assigned to an employee and usually considered as a normal or regular assignment. (2) The contents of a work order.
- job analysis, Determination of the requirements of a job through detailed observation and evaluation of the work performed, facilities required, conditions of work, and the qualifications required of a worker. Syn: job study.
- job breakdown, The systematic division of an operation into elements, or the results of such an analysis. Syn: operation breakdown.
- job characteristic, See job factor.
- job design, See work design.
- job factor, (1) An element characteristic of a job which provides a basis for selecting and training workers and establishing the wage range for the job. Such characteristics include mental and physical requirements, responsibilities, hazards, and other working conditions. (2) A predetermined element of a job evaluation plan against which jobs are compared. Syn: job characteristic.

job skill, The manual and mental proficiency required to perform a given task. Syn: skill.

job standardization, The procedure of specifying a standard practice or a standard method for a job.

job study, See job analysis.

key job, A job that is considered representative of similar jobs in the same plant, company, industry, or labor market and hence may be used for comparing the descriptions of other jobs with the key job for job evaluation and job classification purposes. May also be used as an aid in establishing wages for other jobs.

kymograph, An electronic time study device used to measure extremely short work time intervals. Consists of a system of transducers (principally micro-switches and photoelectric cells) that are activated by an operator performing a job, and a tape puller that records the impulses as a function of time.

labor cost, That part of a firm's total costs attributable to wages, salaries, supplementary benefits, and other employment costs.

labor saving ratio, The labor cost saved by an improved method divided by the unit labor cost of the original method.

labor standard, See direct labor standard, indirect labor standard.

learner's allowance, See training allowance.

learning curve, A plot of productive output or unit work times of an individual or group as a function of time or output per unit time; used to predict the learning rate in starting up a new job or project. A learning curve is usually exponential and flattens out with time. (See start-up curve, progress curve.) Syn: learner's curve.

leveled element time, See normal element time.

leveled time, See normal time.

leveling, See performance rating.

line of flow, See flow line.

loose standard, A standard time greater than that required by a qualified worker with normal skill and effort, following a prescribed method and utilizing allowances for delays, personal needs, and rest.

lost time, See waiting time.

low task, A term used to indicate that performance rating or production standards are based on daywork levels as contrasted to high task or incentive work performance. Sometimes taken to mean a level of performance below the level expected under measured daywork conditions.

machine assignment, (1) The equipment assigned to an operator in the performance of a job. (2) Equipment designed to perform jobs as in production scheduling.

machine attention time, Time during which a machine operator must observe the machine's functioning and be available for immediate servicing. while not actually operating or servicing the machine. Syn: service time.

machine capability, Qualitative and quantitative measures of acceptable output from a given piece of power equipment.

machine-controlled time, The time portion of an operation cycle required by a machine to complete the machine portion of the work cycle. The operator does not control this portion of the cycle time, whether or not attending the machine. Syn: independent machine, machine-controlled time allowance, allowance for machine-controlled time

machine element, See machine-controlled time.

machine hour, A unit for measuring the availability or utilization of machines. It is equivalent to one machine working for 60 minutes, two machines working for 30 minutes, or an equivalent combination of machines and working time.

machine idle time, (1) Time during which a machine is idle during a work cycle awaiting the completion of manual work. (2) interference time.

machine interference, The occurrence of conflicting demands for service by two or more units of equipment.

machine load, (1) The planned usage of a unit of equipment during a specified interval of time. (2) The percentage of maximum load at which the machine is actually used.

machine pacing, Machine or mechanical control over the rate at which the work progresses, as opposed to pacing by the worker(s). (See machine-controlled time.)

machine time, See machine-controlled time.

machine time allowance, See machine-controlled time. allowance.

macroelement, An element of a work cycle long enough to permit observation and timing by a stopwatch. (See microelement.)

maintenance, Preventive and/or correctional activities to insure that facilities and equipment are functionally capable of expected operation. As a result of these activities, equipment should be in good operating condition (clean, free from hazards, etc.) within specified limitations such as those imposed by age and prior use.

man-hour, A unit of measure representing one person working for one hour. The combination of "n" people working for "h" hours produces nh man-hours. Frequent qualifications to the definition include: (1) designation of work effort as normal effort; (2) designation of time spent as actual hours. (See man-minute.)

man-machine chart, See multiple activity process chart.

man-minute, A unit for measuring work. It is equivalent to one person working at normal pace for one minute, two people working at normal pace for thirty seconds, or an equivalent combination of people working at normal pace for a period of time. (See man-hour.)

man-process chart, A graphic, symbolic representation of the work steps or activities performed or to be performed by a person. Typically, the information included on the chart is the distance the person moves and type of work done (by symbol with description). Equipment used and work times may also be included.

manual element, A distinct, describable, and measurable subdivision of a work cycle or operation performed by hand or with the use of tools, and one that is not controlled by process or machine.

- manual time, The time required to perform a manual element. (See manual element.) Syn: hand time.
- manually-controlled work, A work cycle consisting completely of manual elements or where the manual time controls the pace at which the work progresses. Syn: effort-controlled cycle.
- marstochron, An electric motor driven paper-tape puller used to record motion or work element times. An observer visually detects the endpoints of successive motions or elements and presses one or both of two keys that record these endpoints as successive marks along a time base on the tape. Syn: chronograph, marstograph.
- maximum working area, That portion of the working area that is easily accessible to the hands of an operator, with arms fully extended, who is in the normal working position with trunk erect and stationary.
- mean time, See average time.
- measured daywork, (1) Work performed for a set hourly nonincentive wage where performance is compared to established production standards (most frequent use). (2) An incentive plan wherein the hourly wage is adjusted up or down and is guaranteed for a fixed future period (usually a quarter) according to the average performance in the prior period (infrequently used).
- measured work, A term used to describe work, operations, cycles, etc., on which a standard has been set using time study or another standard setting technique.
- mechanization, The act or process of using power-driven machinery to perform specific operations or functions usually with the intent of improving productivity and/or quality of the work performed.
- median time, That time which is greater than or equal to half of the observed times, excluding abnormal times. It is also less than or equal to the other half of the observed times.
- memomotion study, A work measurement and methods analysis technique using a motion picture camera that records events at less than normal camera speed, e.g., 50, 60, or 100 frames per minute. Used for the analysis of long events, group activities, or processes that do not move rapidly. Syn: camera study, time-lapse photography.
- mental work, Work done principally by the mind: logical decision-making, such as sorting, classifying, or inspecting (monitoring); recalling (memory); calculation, such as performing mathematical or verbal operations and inductive policy or hypothesis formulation. The complexity may vary from elementary mental reactions to highly involved judgments based on a large number of variable factors.
- merit rating, A formalized system of appraising employee performance according to an established group of factors. Usually the appraisal is annual or semi-annual and is by immediate supervision. Factors frequently considered include quality of work, quantity of work, reliability, adaptability, initiative, and attitude. (See Production Planning and Control and Wage and Salary Administration.) Syn: performance appraisal, employee rating, personnel rating.
- method, (1) The procedure or sequence of motions by workers and/or machines used to accomplish a given operation or work task. (2) The sequence of operations and/or processes used to produce a given product or accomplish a given job. (3) A specific combination of layout and working conditions; materials, equipment, and tools; and motion patterns involved in accomplishing a given operation or task.
- methods analysis, That part of methods engineering normally involving an examination and analysis of an operation or a work cycle broken down into its constituent parts for the purpose of improvement, elimination of unnecessary steps, and/or establishing and recording in detail a proposed method of performance.
- methods engineering, That aspect of industrial engineering concerned with the analysis and design of work methods and systems, including technological selection of operations or processes, specification of equipment type and location, design of manual and worker-machine tasks. May include the design of controls to insure proper levels of output, inventory, quality, and cost. (See work design, motion analysis, motion economy, methods analysis.)
- methods study, A systematic examination of existing methods with the purpose of developing new or improved methods, tooling, or procedures.
- microchronometer, A large-faced electric clock with rapidly moving hands used in micromotion studies (within the camera's view) to indicate the passage of time. The clock usually measures to the nearest wink, or 0.0005 minutes. Syn: wink counter.
- microelement, An element of work too short in time to allow it to be observed with the unaided eye. (See elemental motion.)
- micromotion study, A work measurement or methods analysis technique using a motion picture camera to record events at normal (960 frames per minute) or faster than normal camera speed. Used for the analysis of short, highly detailed movements that are too rapid for satisfactory visual observation. The camera may be driven so as to act as a timing device for the measurement of motions or elements, or there may be a timing device such as a microchronometer in the camera's field of view. Syn: camera study.
- minimum time, The shortest actual time recorded during a time study for each element of work.
- model time, The actual time value for an element or operation that occurs more often than any other time value.
- motion analysis, The study of the basic divisions of work involved in the performance of a given operation for the purpose of eliminating all useless motions and arranging the remaining motions in the best sequence for performing the operation. (See principles of motion economy.)
- motion cycle, The complete sequence of motions and activities required to do one unit of work or to perform an operation once. (See cycle.)
- motion economy, See principles of motion economy, motion analysis.
- motion study, See motion analysis.
- multiple activity operation chart, See multiple activity process chart.
- multiple activity process chart, A chart of the coordinated synchronous or simultaneous activities of a work system of one or more machines and/or one or more workers. Each

- machine and/or worker is shown in a separate, parallel column indicating their activities as related to the rest of the work system. Examples: multiworker process chart, Gantt chart, multiworker-machine process chart, worker-machine process chart, worker-multimachine process chart. Syn: multiple activity operation chart; multiple activity chart.
- multiple watch timing, See accumulative timing.
- nonballistic motions, See ballistic movement.
- noncyclic element, An element of an operation or process that does not occur every cycle of the operation or process, but its frequency of occurrence in the operation or process is specified by the method.
- nonrepetitive, (1) Generally an operation or process that is performed for only one or a few cycles before it has to be changed significantly to adapt to new requirements. (2) Odd-job production. (3) An operation that does not have a predictable order of elements. (4) An occasional and/or varying element, operation, or job.
- normal effort, The effort required in manual work to produce normal performance. (See normal performance.)
- normal element time, The selected (average, modal, or other) element time adjusted by performance rating to obtain the time required by an average qualified worker to perform a single element of an operation while working at a normal pace.
- normal pace, The manual pace required to produce normal performance. (See normal performance.)
- normal performance, (1) The work output of a qualified employee which is considered acceptable in relation to standards and/or pay levels, which result from agreement with or without measurement, by management or between management and the workers or their representatives. (2) An acceptable amount of work produced by a qualified employee following a prescribed method under standard conditions with an effort that does not incur cumulative fatigue from day to day. (See fair day's work.)
- normal task, See normal performance.
- normal time, The time required by a qualified worker to perform a task at a normal pace to complete an element, cycle, or operation using a prescribed method. (See normal performance.) Syn: base time, leveled time.
- normal working area, (1) The area at the workplace which is bounded by the arc drawn by the worker's fingertips moving in the horizontal plane, with the elbow as a pivot, when the worker is standing or seated in the normal working position with the arm close to the body hanging in a stationary position: the section where the right and left hands overlap in front of the worker constitutes the normal working area for the two hands. (2) In a vertical plane, the space on the surface of the imaginary sphere which would be generated by rotating about the worker's body as an axis, the arc traced by the worker's fingertips of the right or left hand when the forearm is moved vertically about the elbow as a pivot. (3) The space within reach of a worker's fingertips as they develop arcs of revolutions, the elbows acting as a pivot when the worker is standing or sitting in the normal working position with the upper arm hanging from the shoulder close to the body in a stationary position.
- numbering system, (1) A plan for the assignment of numeric keys to items or cases included within a given classification. (2) Means of identifying individual or group arrangements.
- numerical control, A system of controlling a unit, usually a machine tool, whereby either a binary or decimal digit system is programmed to carry out machining operations through electronic circuits and related activating mechanisms.
- objective rating, See performance rating.
- observation, (1) In time study, the act of noting and recording the elapsed time taken by a worker performing an operation or an element of an operation. (2) In motion study, the act of noting and recording the motions used by a worker to perform an operation or an element of an operation. (3) In work sampling, the act of noting and recording what a worker is doing or what is happening in an operation at a specific instant.
- observed time, See actual time.
- occurrence (frequency), (1) The number of times an event takes place, usually in a specific time period. (2) The number of times an element occurs per cycle.
- one best way, The concept that for every job there is an optimal work method that can be developed and specified. A concept originated by Frank and Lillian Gilbreth.
- operation, (1) A job or task, consisting of one or more work elements, usually done essentially in one location. (2) The performance of any planned work or method associated with an individual, machine, process, department, or inspection. (3) One or more elements which involve one of the following: the intentional changing of an object in any of its physical or chemical characteristics: the assembly or disassembly of parts or objects the preparation of an object for another operation, transportation, inspection, or storage; planning, calculating, or the giving or receiving of information.
- operations analysis, A study of an operation or series of operations involving people, equipment, and processes for the purpose of investigating the effectiveness of specific operations or groups so that improvements can be developed which will raise productivity, reduce costs, improve quality, reduce accident hazards, and attain other desired objectives.
- operation breakdown, See job breakdown.
- operation chart, See right and left-hand chart.
- operation process chart, A graphic, symbolic representation of the act of producing a product or providing a service, showing operations and inspections performed or to be performed with their sequential relationships and materials used. Operation and inspection time required and location may be included.
- operation time chart, See operator process chart.
- operator process chart, An operation process chart describing the work done by one operator. (See right- and left-hand chart.) Syn: operation time chart.
- operator productivity, The ratio of standard time or other performance standard to the actual time or other performance measure for the same task. When this ratio is equal to 1.00 (100%) the operator is meeting standard output. (See performance index.) Syn: operator performance.

outlier, In a group of data, a value which is so far removed from the rest of the distribution that its presence cannot be reasonably explained by the random combination of chance causes. (See abnormal time.)

outside work, See external work.

pace rating, See performance rating.

Pareto's Law, Sometimes called the law of the trivial many and the critical few. A principle which states that, in most activities, a small fraction (commonly estimated at 20%) of the total activity creates the major portion (commonly estimated at 80%) of the work, cost, profit, or other measure of importance. Syn: rule of 80-20 (q.v.).

performance evaluation, A critical and objective appraisal of performance measurement data and related information to obtain an accurate picture of the overall status of a specific area or persons to ascertain exceptional accomplishments, identify shortcomings and their causative factors, and develop meaningful recommendations.

performance index, The ratio of a performance standard established for a certain quantity of work to the performance actually achieved. When this ratio is equal to 1.00 (100%) the worker or group is meeting standard performance. (See operator productivity.)

performance indicator, A significant quantitative measure of performance which provides the best perspective of total management effort being applied in an area.

performance measurement, The assessment of accomplishments in terms of historical or objective standards or criteria. (See performance evaluation.)

performance rating, (1) The process whereby an analyst evaluates observed operator performance in terms of a concept of normal performance. (2) The performance rating factor. Syn: leveling, pace rating, effort rating, objective rating.

performance rating factor, The number (usually a percentage) representing the performance rating.

performance rating scale, A numerical scale of performance which may or may not include defined benchmarks. For example, normal performance might be expressed as 100% or 60 minutes per hour. The 100% scale is the most common scale used.

performance ratio, See performance index.

performance sampling, A technique for determining the performance rating factor to be applied to an operator or a group of operators determined by short randomly spaced observations of the performance.

performance standard, A criterion or benchmark to which actual performance is compared.

personal allowance, An allowance to provide time for the personal needs of the worker during the workday. (See allowance.) Syn: personal time.

personal time, See personal allowance.

predetermined motion-time system, See predetermined time system.

predetermined time system, An organized body of information,

procedures, techniques, and motion times employed in the study and evaluation of manual work elements. The system is expressed in terms of the motions used, their general and specific nature, the conditions under which they occur, and their previously determined performance times. Syn: predetermined motion time system.

predetermined time, See predetermined time system.

principles of motion economy, A general listing of common sense steps and procedures to simplify and improve the effectiveness of manual work.

process, (1) A planned series of actions or operations (e.g., mechanical, electrical, chemical, inspection, test) which advances a material or procedure from one stage of completion to another. (2) A planned and controlled treatment that subjects materials or procedures to the influence of one or more types of energy (e.g., human, mechanical, electrical, chemical, thermal) for the time required to bring about the desired reactions or results.

process chart, A graphic, symbolic representation of the specific steps in a processing activity. (See flow process chart, operation process chart, man process chart, flow chart, multiple activity process chart, operator process chart)

process chart symbols, Graphical symbols or signs used on process charts to depict the type of events that occur during a process. (See flow process chart.)

process design, The act of prescribing the production process to produce a product as designed. This may include specifying the equipment, tools, fixtures, machines, and the like required: the methods to be used; the personnel necessary; and the estimated or allowed times. (See methods analysis, process.)

process engineer, An individual qualified by education, training, and/or experience to prescribe efficient production processes to safely produce a product as designed and who specializes in this work. This work includes specifying all the equipment, tools, fixtures, human job elements, and the like that are to be used and, often, the estimated cost of producing the product by the prescribed process. (See process, process design.)

process planning, A procedure for determining the operations or actions necessary to transform material from one state to another.

process sheet, A sketch, diagram or listing of the operations in the sequential order necessary to accomplish the desired result (such as transforming material from one state to another).

process time, (1) Time required to complete the machine or process-controlled portion of a work cycle. (2) Time required to complete an entire process.

processing, The carrying out of a production process. (See process.)

production standard, See standard time.

production study, (1) A detailed analysis of a job, operation, process, or group of activities using the techniques of methods engineering and work measurement with the objective of improvement. (2) An extended time study to determine delay allowances or verify other major variables - sometimes called an eight-hour study.

productive labor, See direct labor.

productive time, Time in which effective work is done in an operation or process, as opposed to nonproductive or idle time.

productivity, (1) The ratio of output to total inputs. (2) The ratio of actual production to standard production, applicable to either an individual worker or a group of workers.

productivity index, See productivity.

progress chart, A graphical representation of the status or extent of completion of work in process. (See Gantt chart.)

progress curve, A plot of work accomplished or productive output versus time. May be accompanied by a plot of expected or planned output for comparison purposes.

qualified operator, A worker who, by virtue of training, skill, and experience, is able to perform a task within acceptable quality and time limits.

random element, See foreign element.

random sample, A sample selected in such a way that each element of the population being sampled has an equal chance of being selected.

rate, (1) Hourly wage rate. (2) To evaluate the observed performance of a task in comparison with some concept of normal performance. (3) The quantity of output produced per unit of time. (4) The quantity of output produced expressed as a percent of either capacity or normal output. (5) Piece rate. (See performance rating.)

rate change, (1) An upward or downward adjustment of a production standard, generally made because of a revision in product design, quality requirements, production methods, materials, or conditions. (2) An upward or downward adjustment in wages paid per unit of time or unit of output.

rate cutting, The arbitrary reduction of a standard time or incentive pay rate. Not considered good practice.

rate setting, (1) The establishment of pay per unit for incentive work. (2) The establishment of a standard time. Syn: rate determination.

rated average element time, See normal element time.

rating, See performance rating.

ratio-delay study, See work sampling.

raw time, See actual time.

reading point, See breakpoint.

regular element, An element of an operation or process that occurs either every cycle of the operation or process or occurs frequently and in a fixed pattern with the cycles of that operation or process as, for example, once every third cycle or four cycles out of five.

relaxation allowance, See fatigue allowance, personal allowance.

repetitive element, See regular element.

repetitive timing, A stopwatch technique where a time value is read and recorded at each breakpoint and the watch is instantaneously reset to zero to begin timing the next element. Syn: snapback timing.

rest allowance, See fatigue allowance, personal allowance.

restricted element, See restricted work.

restricted work, Manual or human-machine work for which the pace or speed of work is not completely under the control of the worker. (See machine-controlled time.)

rework, (1) The process of correcting a defect or deficiency in a product or part. (2) Units of product requiring correction.

right- and left-hand chart, A chart on which the motions made by one hand in relation to those made by the other hand are recorded, using standard process chart symbols or basic therblig abbreviations or symbols. (See operator process chart.)

rule of 80-20, See Pareto's Law.

runout time, Time required by machine tools after cutting time is completed before the tool and material are completely free of interference so that the next sequence of operations can proceed.

select(ed) element time, See select(ed) time.

select(ed) time, The time which is chosen by simple observation or by statistical means as being representative of the actual time values (prior to applying a performance rating factor) obtained from the observation of an element or operation. (See average cycle time, average element time.)

sequencing, Specifying the order of performance of tasks so that available production facilities are utilized in an optimal manner.

setup, Preparation of a workplace or a machine for a specific work method, activity, or process. Includes installation of all necessary hand tools, jigs, fixtures, and other tools or equipment in the location and condition for proper performance of the work.

simo chart, (simultaneous motion chart), A chart for displaying two-handed work with motion symbols plotted vertically against time. The therblig or motion abbreviation and a brief description are shown for each activity. In addition, individual time values and body member detail may be shown. (See right- and left-hand chart.)

simplified practice, (1) The practices or operations resulting from a work simplification or methods study. (2) A description of the work method of a job, specified in somewhat less detail than in a standard practice.

simultaneous motions, Two or more nonconsecutive elemental motions performed during the same time interval by different body members.

skill, See job skill.

snapback timing, See repetitive timing.

speed rating, See performance rating.

standard, (1) An established norm for the measure of quantity, weight, extent, value, quality, or time. (2) Standard time.

standard allowance, An allowance calculated, arbitrarily set, or negotiated to provide in advance for specified conditions. (See allowance.)

standard data, A structured collection of normal time values for work elements codified in tabular or graphic form. The data

- are used as a basis for determining time standards on work similar to that from which the data were collected without making additional time studies. (See synthetic data.)
- standard element time, A standard time for an individual work element. (See standard time.)
- standard hour, The quantity of output required of an operator to meet exactly the production quota for one hour. The production quota is normally based on a standard time. Also used to refer to an hour of less than 60 minutes when allowances are expressed as nonproductive minutes. (See allowed hours.)
- standard output, The reciprocal of standard time expressed in appropriate units (e.g., dozens of units per hour, tons per day, or hundreds of barrels per week).
- standard performance, The performance of a person or group achieving standard output.
- standard practice, A description of a work method wherein all of the significant variables of the method have been specified in detail. Usually follows a specified format. (See method.)
Syn: standard method, written standard practice.
- standard system, The common name for a codified set of time-motion data, often covering both general and proprietary data sets, considered the usual practice for a given plant or location and thus regarded as authoritative. (See predetermined time system.)
- standard time, A unit time value for the accomplishment of a work task as determined by the proper application of appropriate work measurement techniques by qualified personnel. Generally established by applying appropriate allowances to normal time. Standard time and normal time are identical when nonproductive time is granted in lieu of allowances. (See normal performance.) Syn: direct labor standard, engineered performance standard, engineered standard, output standard, production standard, time standard.
- standard time, statistical, A standard time developed from statistical analysis of past performance time data. Syn: historical time.
- standard time data, See standard data.
- standards audit, A work measurement study or sequence of studies intended to test the correctness of existing standard times and methods. By means of periodic sampling of work times, an attempt is made to detect significant changes.
- standby, A category of time in which the worker is not actively engaged in producing a unit of output but is available to take appropriate action when needed. Standby is recognized only when it is essential to the task and when no other work can be done during the standby period. (See delay.)
- standby time, The time expended in standby status. e.g., the time spent by workers in awaiting equipment, labor crews, or work assignment; or due to failure of utilities, inclement weather, and other similar occurrences.
- startup curve, A learning curve applied to a job or process to adjust for work times longer than standard, or average, as a result of the introduction of a new job or new worker(s). (See learning curve.)
- static work, Work performed by the hands or arms where no significant motion occurs, e.g., holding.
- statistical time, See standard time, statistical.
- stopwatch, A portable timing device that can be started or stopped at will by the user to register continuous and/or elapsed time. (See decimal-hour stopwatch, decimal-minute stopwatch.)
- subtracted time, The difference between successive stopwatch readings when using a continuous timing technique. Usually represents the time for one element.
- synchronization allowance, See interference allowance.
- synthetic data, (1) Work measurement time values not obtained from direct measurement of the work to which they are applied. Generally represent values for task elements that are sufficiently basic as to occur in several jobs, obtained from measuring task elements in similar jobs or from predetermined time systems. (2) Any production data not measured directly from but applicable to a given situation (See standard data, predetermined time systems.)
- synthetic time standard, A standard time determined from synthetic data.
- task, See job.
- teardown, All work items required between the end of one operation or job and the start of setup for the next operation or job, both jobs requiring the same machinery or facilities
- temporary rate, (1) An output rate based on a temporary standard. (2) Wage incentive pay rate based on a temporary standard.
- temporary standard, An approximate standard time intended to apply for a limited time to account for some unusual job condition or while awaiting restudy of the task to which it applies.
- therblig, A short manual work segment used to described the sensory-motor activities or other basic elements of an operation. Developed by Frank and Lillian Gilbreth, therbligs form a basic language for methods description and, in modified form, for elemental motion time data. The original seventeen are: search, select, grasp, transport empty, transport loaded, hold, release load, position, pre-position, inspect, assemble, disassemble, use, unavoidable delay, avoidable delay, plan, rest for overcoming fatigue. Syn: Gilbreth basic element, basic division of accomplishment, fundamental motion, basic motion, basic element.
- therblig chart, An operation chart with the suboperations broken down into individual motions, and all motions designated with their appropriate therblig symbols. Syn: right-hand and left-hand chart, simo chart.
- thruput, The quantity of acceptable product processed through a manufacturing line or machine in a specified time (such as an eight-hour shift.)
- tight rate, See tight standard.
- tight standard, A standard time less than that required by a qualified workman with normal skill and effort following a prescribed method and including allowances for delays, personal needs, and rest. Syn: tight rate.
- time allowance, See allowance.
- time formula, A formula for determining the normal time or

- standard time of a task as a function of one or more variables in the task. Included are coefficients for the variables so that insertion of the variable values allows direct time computation.
- time standard, See standard time.
- time study, A work measurement technique consisting of careful time measurement of the task with a time measuring instrument, adjusted for any observed variance from normal effort or pace and to allow adequate time for such items as foreign elements, unavoidable or machine delays, rest to overcome fatigue, and personal needs. Learning or progress effects may also be considered. If the task is of sufficient length, it is normally broken down into short, relatively homogeneous work elements, each of which is treated separately as well as in combination with the rest.
- time study observation sheet, A form for the systematic, detailed recording of element time values, and irregular occurrences observed during a time study. Generally space is also provided for entering other pertinent information and for computation of standard times from the data. Syn: time study computation sheet, time study form.
- tolerance, (1) A permissible variation in a characteristic of a product or process, usually shown on a drawing or specification. (2) In work measurement, the permissible variation of a time value for an operation or other work unit.
- tolerance limits, (1) The upper and lower extreme values permitted by the tolerance. (2) In work measurement, the limits between which a specified operation time value or other work unit will be expected to vary.
- training allowance, (1) An allowance to compensate for an untrained worker's learning effect. (2) An adjustment to an incentive pay piece rate for the same reason. (3) An adjustment to earnings of an individual or group for the same reason. Usually revolves adjusting actual earnings under an incentive plan to some guaranteed percentage, or to prior average earnings. (See allowance.) Syn: learner's allowance.
- travel chart, A table giving distances travelled between points in a manufacturing facility. Values may be adjusted to reflect weight, value, or some other factor depending on circumstances.
- travel time, Time required to move material, equipment, personnel, or information from one work or storage area to another.
- unavoidable delay, A delay which is outside the control or responsibility of the worker.
- unavoidable delay allowance, An allowance intended to provide time for expected unavoidable delays in a task. (See allowance. unavoidable delay.)
- unrestricted element, An operation element that is completely under the control of the worker. Syn: manual element.
- unrestricted job, A job that is completely under the control of the worker.
- value analysis, Review of product costs to evaluate contribution to product value. May include phases of work design, methods engineering, and motion economy to reduce manufacturing costs. May include phases of work simplification and brainstorming to evaluate use of alternate materials, components, or work specifications.
- value engineering, See value analysis.
- variable element, (1) An element whose normal time varies significantly from cycle to cycle as a function of one or more job variables. (2) An element common to two different jobs and whose time varies due to differences between the jobs.
- waiting time, The time a unit waits for service or a worker waits for parts. (See standby.) Syn: idle time.
- wink, One division on the microchronometer equal to 1/2,000 (.0005) minute.
- wink counter, See microchronometer.
- work cycle, (1) A pattern or sequence of tasks, operations, and/or processes. (2) A pattern of manual motions, elements, operations, and/or activities that is repeated without significant variation each time a unit of work is completed. (See motion cycle.)
- work design, The design of work systems. System components include people, machines, materials, sequence, and the appropriate working facilities. The process technology and the human characteristics are considered. Individual areas of study may include analysis and simplification of manual motion components; design of jigs, fixtures, and tooling; human-machine analysis and design; or the analysis of gang or crew work. Syn: ergonomics, job design, methods engineering, methods study, motion study, operation analysis, work simplification, motion economy.
- work measurement, A generic term used to refer to the setting of a time standard by a recognized industrial engineering technique, such as time study, standard data, work sampling, or predetermined motion time systems. Syn: ergonomometrics.
- work sampling, An application of random sampling techniques to the study of work activities so that the proportions of time devoted to different elements of work can be estimated with a given degree of statistical validity.
- work simplification, A management philosophy of planned improvement using any or all of the tools and techniques of industrial engineering in an atmosphere of creative participation which enables employees to achieve individual goals through the achievement of organizational goals. (See work design.)
- work station, See workplace.
- work study, The techniques of methods study and work measurement employed to ensure the best possible use of human and material resources in carrying out a specific activity.
- work task, A specific quantity of work, set of duties or responsibilities, or job function assigned to one or more persons.
- working area, That portion of the workplace within which an operator moves about in the normal job performance.
- working conditions, The condition of the physical environment within which people work. The environment includes the presence and amount of illumination, heat, air movement and pollution, radiation, cleanliness, spaciousness, and safety. It may also include the conditions of the social environment, including type and intensity of supervision, emotional impact of the nature of the job, and opportunities for interaction with peers.

workplace layout, The manner in which all of the items necessary to perform a work task, as specified by the standard method, are arranged.

written standard practice, See standard practice.



BASIC PROCEDURE

When any problem is examined there should be a definite and ordered sequence of analysis. Such a sequence may be summarized as follows:

1. DEFINE the problem.
2. OBTAIN all the facts relevant to the problem.
3. EXAMINE the facts critically but impartially.
4. CONSIDER the courses open and decide which to follow.
5. ACT on the decision.
6. FOLLOW UP the development.

We have already discussed the basic procedure for work measurement. Let us now examine the basic procedure for method study, selecting the proper steps. They are as follows:

1. SELECT the work to be studied.
2. RECORD all the relevant facts about the present method by direct observation.
3. EXAMINE those facts critically and in ordered sequence, using the techniques best suited to the purpose.
4. DEVELOP the most practical, economic, and effective method, having due regard to all contingent circumstances.
5. DEFINE the new method so that it can always be identified.
6. SELL the change to assure a smooth transition to the new method.
7. INSTALL that method as standard practice.
8. MAINTAIN that standard practice by regular routine checks or through the use of a Labor Reporting System.

These are the eight essential stages in the application of method study; none can be excluded. Strict adherence to their sequence, as well as to their content, is essential for the success of an investigation.

Do not be deceived by the simplicity of the basic procedure into thinking that method study is easy and therefore unimportant. On the contrary, method study may on occasion be very complex, but for purposes of description it has been reduced to these few simple steps.



Section III Selecting the Work To Be Studied

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CUES/INDICATORS - WHERE TO START

Work simplification can only be accomplished with an open mind. Do not take any method for granted, no matter how long it has been done one way or how good the present method seems. Remember there is always a better way.

The technique of work simplification, more than anything, relies on good common sense and a few logical steps. First, establish a job or function you want to improve. Look for jobs that have many delays, bottlenecks, poorly maintained machines, excessive set-up time, etc.

Second, break down the job so it can be effectively analyzed. It is much easier to analyze a job when it is broken down into small elements so attention can be paid to one element at a time.

A number of tools and techniques can be used to break down a job. These will be covered in depth in this course. However, one very important tool is worth going into detail at this time: the "questioning" attitude of the methods engineer.

"Why" is the most important question and should be asked first and then applied in turn to each of the other questions: What, Where, When, Who, and How as follows:

Where should it be done?
Change sequence?

Why should it be done there?
Combine?

When should it be done?
Change sequence?

Why should it be done then?
Combine?

Who should do it?
Eliminate?

Why should he/she do it?
Change sequence?

How should it be done?
New process?

Why should it be done that way?
Change method?

We ask these questions so that the answers may lead us to eliminating, combining, rearranging, and/or simplifying some of the activities.

Work simplification leads to productivity improvement: the key to healthy business, job security, accomplishment, and quality in work life.



WHAT TO ANALYZE AND MEASURE

When considering whether a method study investigation of a particular job should be carried out, certain factors should be kept in mind. These are:

- Economic considerations
- Technical considerations
- Human reactions.

1. Economic considerations will be important at all stages. It is obviously a waste of time to start or to continue a long investigation of the economic importance if the job is small, or if it is one which is not expected to run for long. The first questions must always be: "Will it pay to begin a method study of this job?" and "Will it pay to continue this study?"

Obvious early choices are:

- "Bottlenecks" which are holding up production operations
 - Movement of material over long distances between shops, or operations involving a great deal of manpower or where there is repeated handling of material
 - Operations involving repetitive work using a great deal of labor and liable to run for a long time.
2. Technical considerations will normally be obvious. The most important point is to make sure that adequate technical knowledge is available with which to carry out the study. Examples are:
 - (a) The use of preconstruction primer versus raw steel in the construction process might bring increased productivity of facilities and labor, but there may be technical reasons why a change should not be made. This calls for advice of specialists in welding, burning, coatings, etc.
 - (b) A machine tool constituting a bottleneck in production is known to be running at a speed below that at which the high-speed cutting tools will operate effectively. Can it be speeded up, or is the machine itself not robust enough to take the faster cut? This is a problem for the machine-tool expert.
 3. Human reactions are among the most important factors to be taken into consideration, since mental and emotional reactions to investigation and changes of method have to be anticipated. If it appears that the study of a particular job is leading to a great deal of unrest or ill feeling, you may decide to leave it alone for the time being, however promising it might be from the economic point of view. If other jobs are tackled successfully and can be seen by all to benefit the people working on them, opinions will change and it will be possible, in time, to go back to the original choice.



When selecting a job for method study it will be found helpful to have a standardized list of points to be covered. This prevents factors from being overlooked and enables the suitability of different jobs to be easily compared. A sample list is given below which is fairly full, but lists should be adapted to individual needs:

1. Production and operation
2. Person who proposes investigation
3. Reason for proposal
4. Suggested limits of investigation
5. Particulars of the job:
 - (a) How much is (many are) produced or handled per week?
 - (b) Will more or less be required in future?
 - (c) How long will the job continue?
 - (d) HOW many employees are employed on the job:
 - a. directly?
 - b. indirectly?
 - (e) How many employees are there in the trade?
 - (f) What is the average output per day?
 - (g) What is the daily output compared with the output over a shorter period? (e.g., an hour)
 - (h) What is the daily output:
 - a. of the best employee?
 - b. of the worst employee?
 - (i) Has the job any especially unpleasant or injurious features? Is it unpopular:
 - a. with workers?
 - b. with supervisors?



6. Equipment:

- (a) What is the approximate cost of plant and equipment?
- (b) What is the present ratio of Machine Running Time to Machine Available Time?

7. Layout:

- (a) Is the existing space allowed for the job enough?
- (b) Is extra space available?
- (c) Does the space already occupied need reducing?

8. Product:

- (a) Are there frequent design changes causing modifications?
- (b) Can the product be altered for easier manufacture?
- (c) What quality is demanded?
- (d) When and how is the product inspected?

9. What savings or increase in productivity may be expected from a method improvement:

- (a) Through reduction in the work content of the product or process?
- (b) Through better machine utilization?
- (c) Through better use of labor?

(Figures may be given in money, man-hours or machine-hours, or as a percentage).

Item 4, "suggested limits of investigation", deserves some comment. It is important to set clearly defined limits to the scope of the investigation. Method study investigations so often reveal scope for even greater savings that there is a strong temptation to go beyond the immediate object. This should be resisted, and any jobs shown up as offering scope for improvements through method study should be noted and tackled separately.

Such a list will prevent the work-study analysis from going first to a small bench job which will entail a detailed study of the worker's operation and yield a saving of a few seconds per operation, unless the job is one that is being done by a large number of operatives, so that the total saving will significantly affect the operating costs of the plant. It is no use playing around with split seconds and inches of movement when a great waste of time and effort is taking place as a result of bad shop layout and handling of heavy materials.



Section IV Record and Analyze the Method

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Typical Panel Assembly Operation 23

Booklet: "Process Charts"

Flow Charts

Linear Responsibility Charting 28

Article: "Linear Responsibility Charting"





RECORDING THE FACTS

The next step in the basic procedure, after selecting the work to be studied, is to record all the facts relating to the existing method. The success of the whole procedure depends on the accuracy with which the facts are recorded, because they will provide the basis of both the critical examination and the development of the improved method. It is therefore essential that the record be clear and concise.

The usual way of recording facts is to write them down. Unfortunately, this method is not suited to the recording of the complicated processes which are so common in shipbuilding. This is particularly so when an exact record is required of every minute detail of a process or operation. To describe exactly everything that is done in even a very simple job which takes perhaps only a few minutes to perform would probably result in several pages of closely written script. This would require careful study before someone reading it could be quite sure that he had grasped all the detail.

To overcome this difficulty, other techniques or "tools" of recording have been developed so that detailed information may be recorded precisely and at the same time in standard form, in order that it may be readily understood by all.

The most commonly used of these recording techniques are charts and diagrams. There are several different types of standard charts available, each with its own special purpose.



OPERATION ANALYSIS

Operation analysis is a systematic procedure used to study all the factors which could affect the method of performing an operation economically. Through this analysis, the present best available method of performing each necessary step of an operation is determined and improved if possible.

To simplify the analysis procedure, an operation analysis form has been specifically designed for shipbuilding. The form is intended to act as a guide to systematically analyze operations. It will direct you in making the analysis through the key factors considered and ensures that none of them are overlooked. Consider each of the factors in detail. The primary factors which should be reviewed in every operation follow:

1. Purpose of operation
2. Part design
3. Material
4. Material handling
5. Inspection requirements
6. Process analysis
7. Design of work
8. Workplace layout, machine, and tools
9. Working conditions
10. Other areas for possible improvements
11. Methods comparison chart

The form was designed to provide a record of the conditions that exist at the time of the analysis and to suggest any possible improvements. Record all pertinent data clearly and concisely.

All backup documentation should be attached to the operation analysis form.

The form is a general indicator of the course along which you should proceed. Each factor that indicates areas for improvement should be studied in greater detail utilizing the techniques of methods engineering to sufficiently document reasons for change.

It must be remembered that the operation analysis form is merely a tool which can be used to analyze an operation. It is principally designed to guide and keep clear the points that should be reviewed when seeking improvement. You might develop your own check questions also. Any improvement that is made will be the result of your ability to use sound reasoning, constructive thinking, and creativity; no form can do this for you.

Page 1

DATE _____

DWG. NO. _____

HULL NO.

[illegible]

ACTION	ANALYSIS CONSIDERATIONS	DESCRIPTION
	Are standard sizes utilized to the maximum?	B. POSSIBLE SUBSTITUTE
	Is material purchased in a condition suitable for use?	
	Is material sufficiently clean?	
	Is material purchased as part of a production schedule that brings the material into the operation at the right time?	C. WAYS TO REDUCE SCRAP COSTS
		D. PROCESS MATERIALS
	Can number of moves be reduced?	4. MATERIAL HANDLING
	Can material be located at job site?	A. TRANSPORTED TO WORK PLACE BY:
	Does material flow coincide with general yard material flow?	
	Are proper containers being utilized?	
	Is proper means of handling being used (ex: crane v. truck)?	
	Can signals be used to notify material handlers?	B. HANDLED AT WORK STATION BY:
	Is material used at a convenient height, or is it stored on the ground?	
	Is there a priority system established to minimize expensive delays?	
	Is material handling equipment used in the best way?	C. REMOVED FROM WORK STATION BY:
	What are chances for material to be lost during handling?	
	Is time spent bringing material to the work station and hauling it away, long, in proportion to the operating time?	
	Are areas for incoming and outgoing material located properly?	D. CONTAINER?
	Are additional conveyors justified?	
	How about turntables?	
	Are present inspection requirements	5. INSPECTION REQUIREMENTS
	A. sufficient?	A. SPECIFICATIONS AND TOLERANCES
	B. necessary?	
	C. effective?	
	Are tolerances realistic?	
	Do all concerned know the quality requirements?	
	Do previous or following inspections duplicate the present inspections?	
	Are standards for this operation compatible with the standards of other similar operations?	B. INSPECTION METHOD
	What are main causes of rejection for this part?	
	Is quality standard definitely fixed, or is it a matter of individual judgment?	
	Does the quality circle concept have an opportunity here?	

[illegible]

ACTION	ANALYSIS CONSIDERATIONS	DESCRIPTION
	<p>LAYOUT:</p> <p>A. Can work area be improved?</p> <p>B. Does the layout design aid efficient material handling?</p> <p>C. Is work area organized?</p> <p>D. Does the layout provide adequate safety?</p> <p>E. Are tools, materials, and supplies placed properly? Consider racks, shelves, etc.</p> <p>F. Has provision been made for the storage of the operator's personal belongings?</p> <p>G. Can distances be shortened?</p> <p>H. Can body motions be reduced in number?</p> <p>I. Are adequate working surfaces provided for secondary operations, i.e. inspection, deburring, counting, slag removal, etc.?</p> <p>J. Are chips, slag, cuttings, weld rods, ends, etc. removed promptly and adequately?</p> <p>K. Is there a computer HOST workplace area sketch sheet? File No. _____</p>	<p>8. WORKPLACE LAYOUT (Indicate possible improvements)</p>
	<p>TOOLS:</p> <p>A. Are tools suitable for job?</p> <p>B. Can jigs or fixtures be used? (Hands are poor holding devices)</p> <p>C. Are tools being used correctly?</p> <p>D. Is the fixture designed for maximum motion economy?</p> <p>E. Does the foreman make sure all operators have the current tools?</p> <p>F. Would a special bench eliminate stooping or bending?</p>	
	<p>MACHINES:</p> <p>A. Can machine be easily adjusted?</p> <p>B. Can operator run more than one machine?</p> <p>C. Can operator do other operations internal to machine time?</p> <p>D. Is the machine being utilized to its fullest potential?</p> <p>E. Would a special machine do the job better?</p> <p>F. Is the volume sufficient to develop a special machine?</p> <p>G. Is the machinery in good operating condition; is it maintained?</p> <p>H. Do machines have stops, guides, indicators, etc., so as to facilitate production?</p> <p>I. Are quick-acting clamps used where indicated?</p> <p>J. Are there opportunities for N/C or CAD/CAM?</p> <p>K. How about robots?</p> <p>L. Have you looked into group technology (GT) where grouping by families of parts is tried, but also families of related processes - and then optimize work flow by combining the two?</p>	

ACTION	ANALYSIS CONSIDERATIONS	DESCRIPTION
	Is the lighting adequate for the job? (all shifts)	9. WORKING CONDITIONS
	Is the floor or walking surface smooth and safe?	(possible improvements)
	Free from unnecessary obstructions?	
	Has the operator been taught to work safely, especially considering the safety of others?	
	Does the plant present a neat and orderly appearance at all times?	
	Is the ventilation adequate? Are dangerous processes adequately guarded - both from the standpoint of the operator and passerby?	
	If the process makes pollution, are these designed in a way to reduce or eliminate it?	
	Is work designed to foster teamwork and cooperation between workers and between workers and supervision?	
	Is the operator and foreman proud of their finished product?	
	If the job is boring or monotonous, can it be made more interesting? Safety or productivity might result.	10. OTHER AREAS FOR POSSIBLE IMPROVEMENTS
	Can the operator do his own maintenance?	
	Is job rotation possible, and desirable?	
	Can fixed teams of journeymen be used?	
	Can buffer stock be provided to allow variations in the work pace?	
	Are records being kept that no one looks at?	
	Can any record keeping be eliminated?	
	If you we re operator, what changes would you want?	
	Are workers encouraged to suggest improvements?	
	When you do increase productivity are you set up to measure the improvement and report it to management?	
	Are you avoiding the traps of "short term results" and losing the advantage of the best solution?	
	Does your own attitude, contacts with operators and foremen, etc. encourage wide involvement in productivity improvements?	
	Have you spent adequate time in the production area so you understand what is going on?	
	Look for and eliminate or reduce delays and interruptions.	
	Use improvements from other jobs.	
	Compare methods of several different operators on the same job.	
		REMEMBER -
		Many times there is no quick, easy, miracle cure. The main solution often involves basic business fundamentals, motivation, common sense, and the plain hard work of one person doing something. But the accomplishment that results from this can be very satisfying indeed.

[illegible][illegible]

FLOW PROCESS CHART

SUBJECT _____ DATE _____

CHART BEGINS

CHART ENDS _____

[illegible]

FLOW PROCESS CHART

SUBJECT _____ DATE _____

CHART BEGINS_____

CHART ENDS _____

[illegible]

FLOW PROCESS CHART

SUBJECT _____ DATE _____

CHART BEGINS

CHART ENDS _____

[illegible]

AMERICAN NATIONAL STANDARD

Process Charts

ANSI Y15.3M-1979

(REVISION OF ANSI Y15.3-1974)

SECRETARIAT

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

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FOREWORD

This revision is based on the previous work of the ASME Special Committee on the Standardization of Therbligs, Process Charts, and Their Symbols, as documented in the previous edition of this standard, ANSI Y15.3-1974 (ASME Standard 101-1972), Operation and Flow Process Charts. In 1978, the ASME Committee was reorganized and redesignated Subcommittee 3, Process Charts, of the American National Standards Committee Y15, Preferred Practice for The Preparation Of Graphs, Charts, And Other Technical Illustrations.

The initial effort on standardizing Therbligs, Process Charts and Their Symbols was based on concepts originated and developed by Dr. Frank B. and Dr. Lillian M. Gilbreth. These include definition, scope and the symbols of pure motions and their corresponding charting and analysis forms. In preparing this revision the Committee avoided fundamental changes in definitions and concepts which were contrary to actual practices in industry. Substantive changes without cost/benefit justification or those which might result in some economic injury to the practitioner were discarded.

The proposed revisions include: (a) simplifying the title and general structure of the standard which explains charting techniques and conventions, (b) modifying definitions to promote clarity, (c) adding new charts and drawings and (d) deleting obsolete material.

This revision was approved by the American National Standards Institute on December 17, 1979.

AMERICAN NATIONAL STANDARDS COMMITTEE Y15
Preferred Practice For The Preparation of Graphs,
Charts, And Other Technical Illustrations

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AMERICAN NATIONAL STANDARD

PROCESS CHARTS

1 GENERAL

1.1 Scope

This standard presents the definition of process charts, charting procedures and the principles and practices for their construction. The forms and conventions illustrated in this standard represent current definitions and concepts from industry.

Process charts provide a systematic description of a process or work cycle involving activities of humans, agents or objects. Because a common medium of expression is used, a single process chart may serve the needs of many individuals either performing, managing, or analyzing the work. process charts have a variety of uses, the most frequent being analysis, methods improvement, job instructions and training.

1.2. Definition of a Process Chart

A process chart is a schematic or tabular representation of the sequence of all relevant actions or events-operations, transportations, inspections, delays, storages (and the like)-occurring during a process or procedure, and includes information considered desirable for analysis such as time required and distance moved. Two types of process charts are used.

(a) The material type presents the process in terms of the events which occur to the material(s) being processed.

(b) The person-type presents the process in terms of the activities of a person(s) performing steps of the process.

1.3 Process Charting Procedure

For analytical purposes and to aid in detecting and eliminating inefficiencies, it is convenient to classify the actions which occur during a given process into five actions or activities. These are known as operations, transportations, inspections, delays, and storages. The following definitions cover the meaning of these activities under the majority of conditions which will be encountered in process charting work.

1.4 Activities Defined

1.4.1 Operation. An operation occurs when an object is intentionally changed in any of its physical or chemical characteristics, is assembled or disassembled ~~from another~~ another object, or is arranged or prepared for another operation, transportation, inspection, or storage. An operation also occurs when information is given or received or when planning or calculating takes place. (Symbol: Circle)



1.4.2 Transportation. A transportation occurs when an object is moved or a person moves from one location to another, except when such movement is part of the operation or is caused by the operator at the work station. (Symbol: Arrow)



1.4.3 Inspection. An inspection occurs when an object is examined for identification or is verified for quality or quantity in any of its characteristics. (Symbol: Square)



1.4.4 Delay. A delay occurs when an object or person waits for the next planned action. (Symbol: D)



1.4.5 Storage. A storage occurs when an object is kept and protected against unauthorized removal. (Symbol: Inverted Triangle)

1.4.6 Combined or modified symbols. Progress is always developing variations from existing conditions. In the advances made in diagraming office work, data processing, materials handling and warehouse operations, situations have arisen where it is desirable to vary or combine basic symbols. Examples follow:

(a) Variation. The Operation symbol has been modified in paperwork applications to indicate:



Creation of a record or a set of papers.
(Symbol: Encircled Circle)



Addition of information to a record
or set of papers. (Symbol: Shaded Circle)

(b) Combination. Symbols have been combined to show activities performed concurrently:

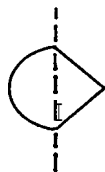


Inspection performed within an operation.
(Symbol: Circle in Square)



Operation performed while product is in
motion. (Symbol: Arrow in Circle)

(c) Modification. Symbols have been joined to aid distinction:



Handling (half an operation and half a transportation), as when picking-up, setting-down, where no operation is performed yet no distance is involved in that portion of the "transport." (Symbol: Half Circle-Half Arrow)

1.4.7 When unusual situations outside the range of the definitions are encountered, the intent of the definitions summarized in the following tabulation will enable the analyst to make the proper classifications.

Action/Activity	Predominant Result
Operation	Produces or Accomplishes
Transportation	Moves
Inspection	Verities
Delay	Interferes
Storage	Keeps

1.4.8 The following criteria should serve as a guide for the shape of the symbols: (1) should be readily distinguished from other symbols; (2) should provide room for writing within it, either alone or when combined with other symbols; (3) should combine readily with other symbols; (4) should be used in only one orientation; (5) should be capable of being drawn free hand easily. Poor draftsmanship should not result in confusion with another symbol.

Frank B. and Lillian M. Gilbreth devised the first symbols for process charts. Those presented above follow the Gilbreths' symbols for the actions, operation, inspection, and storage, but differ with respect to transportation and delay (temporary storage). They use a small circle for transportation, which violates criteria 2 and 5, and a double triangle, one within the other, for temporary storage, which violates criteria 2 and 4, namely, it uses variations of the same geometric form, the triangle, for two actions.

2 PRINCIPLES AND PRACTICES FOR CONSTRUCTION OF PROCESS CHARTS

2.1 Form

Process charts differ widely from one another because of the nature or scope of the processes they portray. They are usually drawn on *plain paper* of sufficient size to accommodate them when they portray the events occurring to more than one item of material, the activities of more than one person, or the alternate routes or procedures followed by material or people. When events occurring to a single item or the activities of a single person are charted, *prepared forms* may be used.

2.2 Identification

The identifying information which is always necessary is as follows:

Subject Charted
Present Method or Proposed Method
Drawing number, part number, or other identifying number
Date Charted
Charted by

2.3 Major Conventions-Schematic Charts (on plain paper)

2.3.1 The major axis of a process chart may be either horizontal or vertical. The following conventions apply to a vertically oriented chart, or to a horizontal chart which has been rotated ninety degrees in a clockwise direction.

2.3.2 The sequence in which the events depicted on the chart must be performed is represented by the arrangement of process chart symbols on vertical flow lines. Material, either purchased or upon which

work is performed during the process, is shown by horizontal material lines feeding into the vertical flow lines.

2.3.3 One of the parts going to make up the completed product is selected for charting first. Usually this is the component on which the greatest number of operations is performed, the dominant material, or the part having the greatest bulk to which the smaller parts are assembled.

This is typically placed in the upper right hand corner. See Figure 1 (d)

2.3.4 These conventions have been developed for use in making process charts, and are shown on figure 1.

(a) Horizontal lines indicate materials being fed into the process. Lines are drawn vertically to show the steps of the process in chronological sequence.

(b) The vertical process lines take precedence when they are to be crossed by material in feed or distribution lines.

(c) The typical process chart consists of symbols representing a series of actions and information shown in sequence with connecting lines and with appropriate numbers noted inside.

(d) Charts of assembly operations are started in the upper right hand corner with the largest component or the one having the most operations.

(e) Alternate routings are shown by splitting and rejoining lines.

(f) Materials being returned for rework are portrayed by backtracking lines to the point or points where operations start to repeat.

(g) Losses from processes are indicated by separate down-flowing lines.

(h) Directions of flow in complex charts are shown by arrows,

2.3.5 Figures 2 and 3 show examples of activity identification conventions and the use of these conventions. In Figure 2, only operations and inspections are shown. This type of process chart has traditionally been known as an Operation Process Chart. In Figure 3, all activities are deemed pertinent, so all are shown. This chart shows the manner in which several components are processed and brought together to make the completed product. In this case, facing sand. A horizontal process chart, without the

discipline of symbols, but with more information about the process, is shown as Figure 4.

2.3.6 Operations are numbered serially for identification and reference purposes in the order in which they are charted. The first operation is numbered 1, the second 2, and so on. When another component on which work has previously been done joins the process, the operations performed upon it are numbered in the same series. If the first component on the chart has had four operations performed upon it, they will be identified as 1, 2, 3 and 4. If a second component then joins the first, the first operation performed on the second component will be identified as 5. If two more operations are performed on the second component before it joins the first, they will be numbered 6 and 7. The first operation performed after two components have come together would then be identified as 8 (set screw and adjusting screw). See Figure 2.

2.3.7 An operation number once used is never repeated on the same chart. If after a chart has been completed, it becomes necessary to add an operation to the process between two operations, it is permissible to identify the new operation with the number of the preceding operation followed by the subscript "a". Thus an operation inserted between 4 and 5 would be identified as 4a.

2.4. Other Conventions-Schematic Charts

2.4.1 The conventions followed for portraying disassembly operations are quite similar to those used for assemblies. Material is represented as flowing from the process by a horizontal material line drawn to the right from the vertical process sequence line approximately $\frac{1}{4}$ inch (5 mm) below the symbol for the disassembly operation. The name of the disassembled component is shown directly above the horizontal material line. The subsequent operations which are performed on the disassembled component, if any, are shown on a vertical process sequence line extending down from the right hand end of the horizontal material line.

2.4.2 If the disassembled component is later reassembled to the part or assembly from which it was disassembled, that part or assembly is shown as feeding back into the process sequence line of the component. This practice moves the major vertical process line always to the right. Thus, when disassembly operations are to be shown, the chart cannot be started

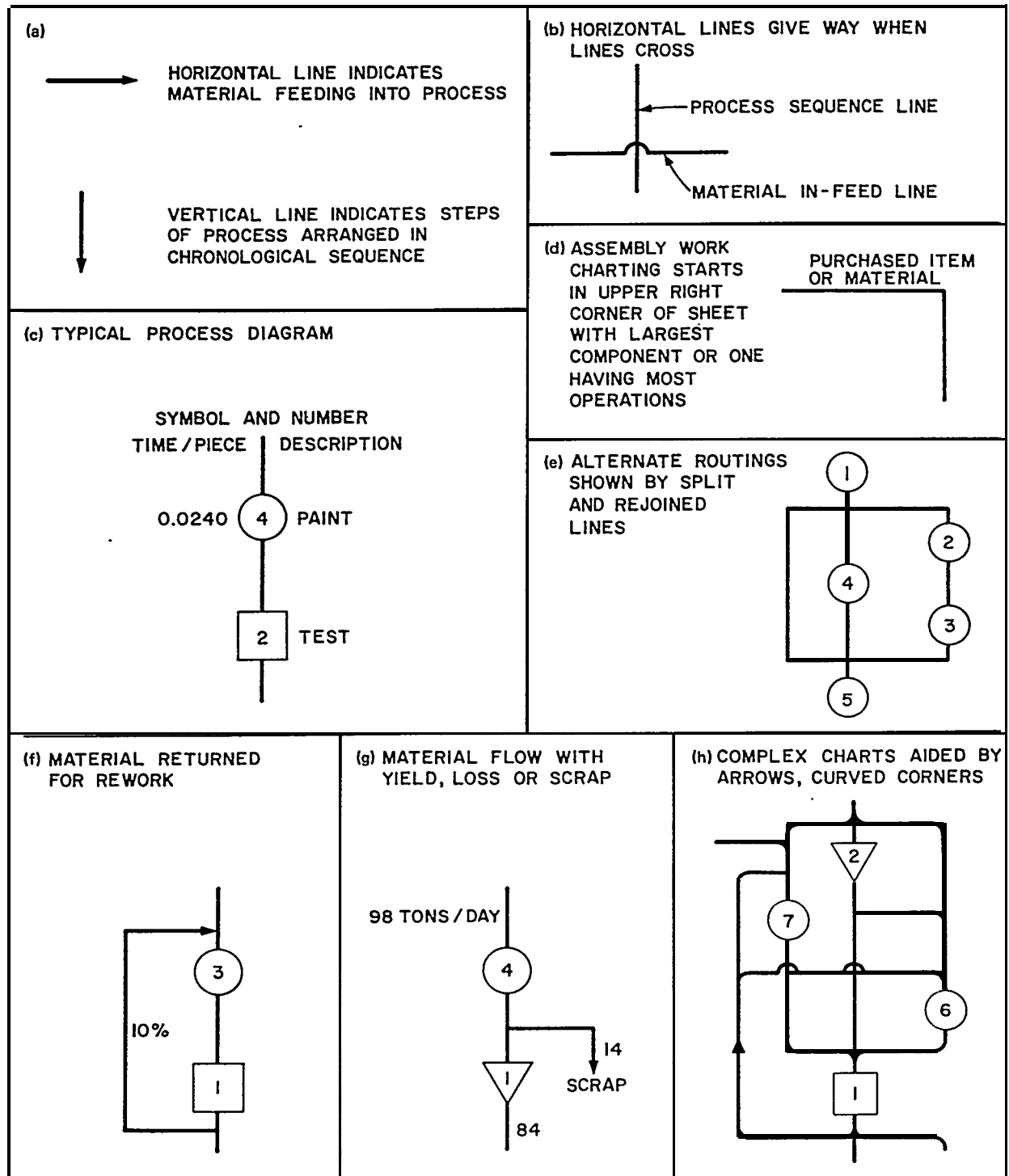


FIG. 1 CONVENTIONS AND MODIFICATIONS IN MAKING PROCESS CHART

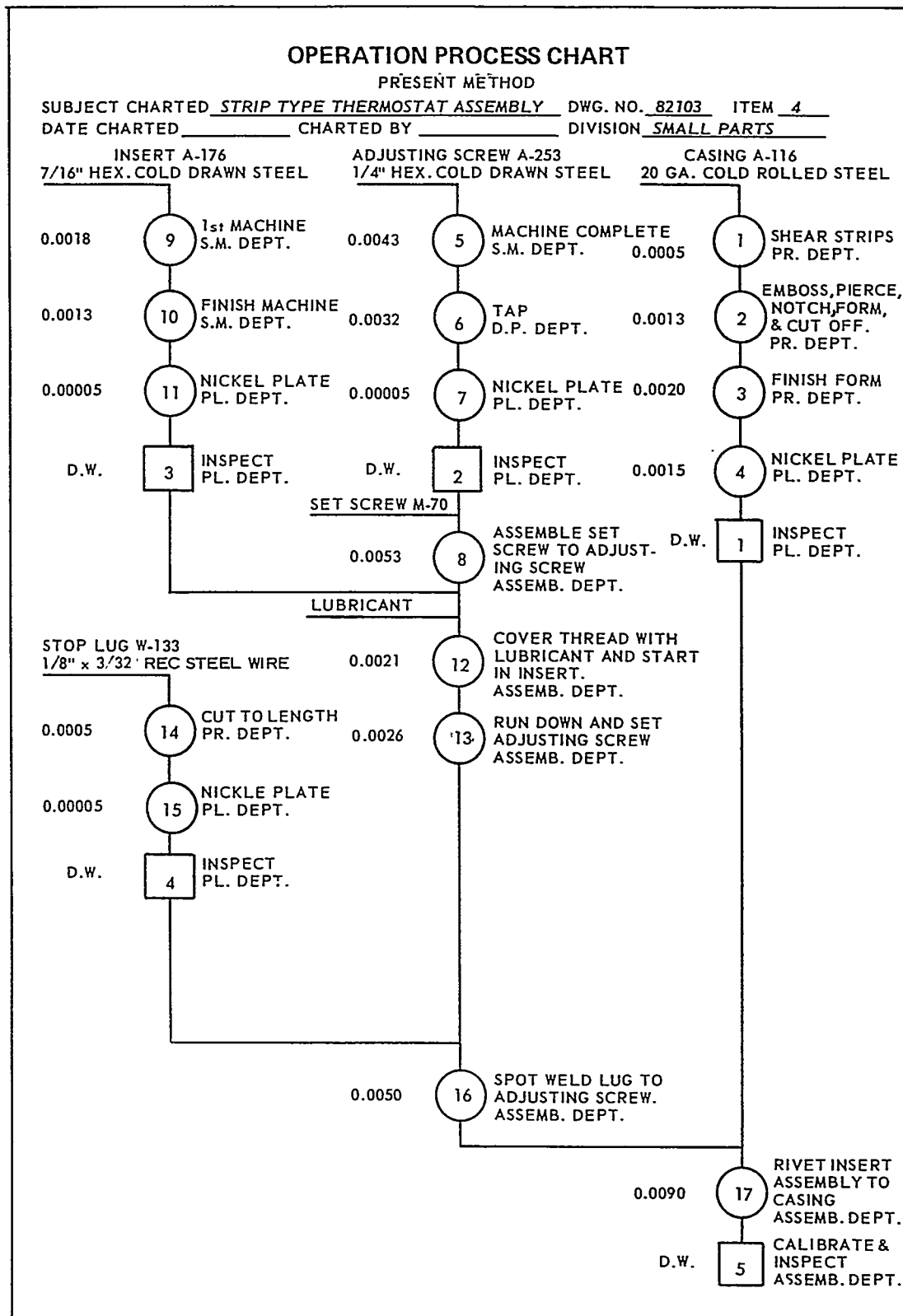


FIG. 2 TYPICAL OPERATION PROCESS CHART



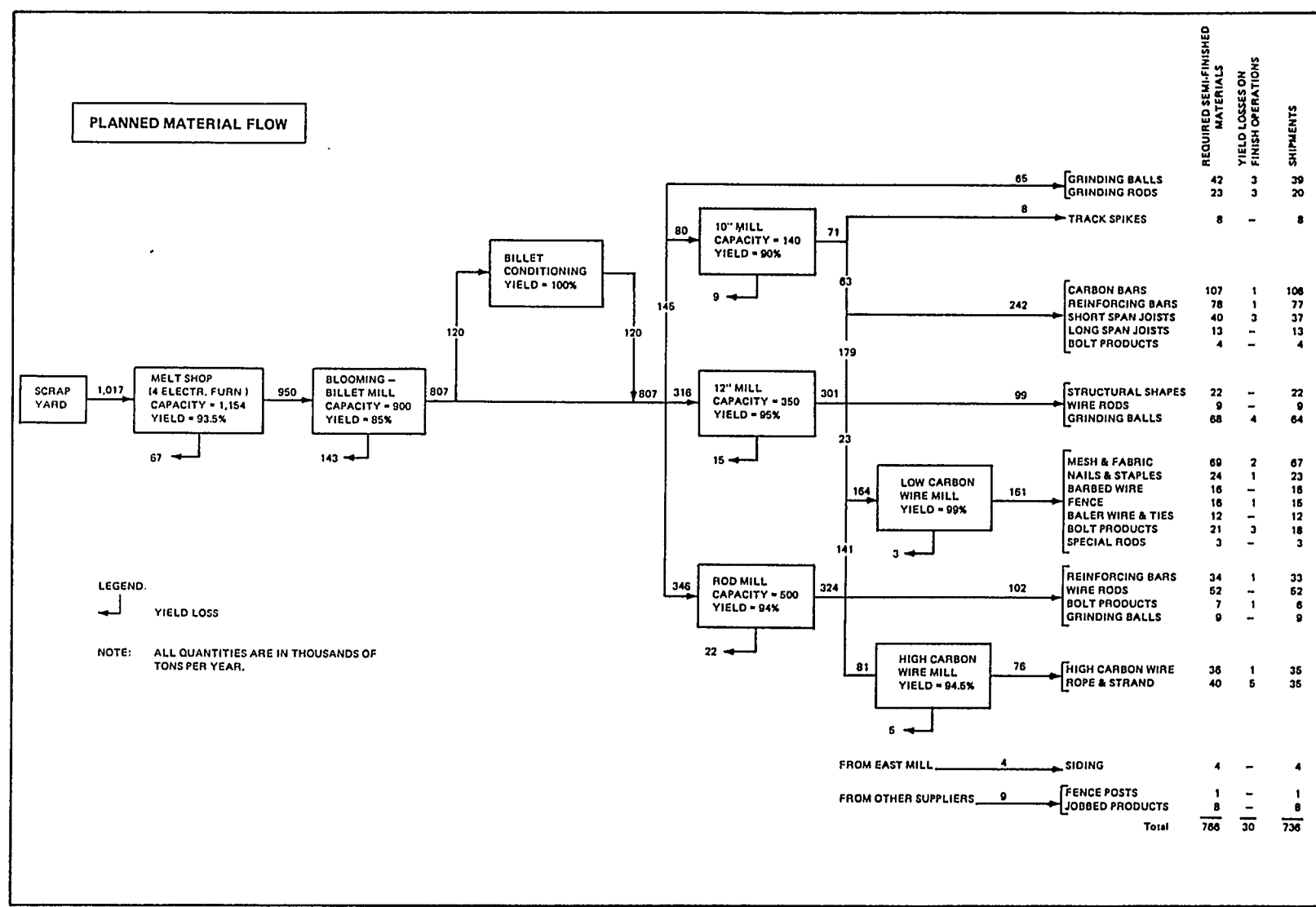


FIG. 4 PLANNED MATERIAL FLOW — A FORM OF PROCESS CHART WITHOUT USE OF CONVENTIONAL SYMBOLS. A form of process chart used in planning major expansion of a steel mill complex. Here each rectangle represents a major activity-area; numbers beside each flow line represent thousands of tons per year; and yield loss is shown by the back-flow arrow. This shows the break-down of a basic material into various derivative products, rather than the build-up into an assembled product as in Figure 2.

in the upper right hand corner of the form, but must be started further to the left.

2.4.3 It is the practice to number the operations performed on the disassembled component after disassembly before numbering the operations on the part from which it was disassembled. Then if the part later rejoins the disassembled component, the conventional numbering practices may be followed. This practice also applies to inspections.

2.5 Major: Conventions-Tabular Charts (on prepared form)

2.5.1 There is enough similarity among process charts of single items to permit the use of prepared forms which are both convenient and time saving. The simplest of these forms provides headings for chart symbols, process description, distance moved and time. The process data and symbols stand out clearly, as shown by Figure 5. It shows the process for making door protectors.

2.5.2 Figure 6(a) is a more detailed process chart of the present method of handling air freight drawn on a form with preprinted symbols and columns for recording distance, quantity and time. Connecting the appropriate symbols with a continuing line obviates the need for drawing symbols with a template. When all five symbols are used or indicated on the chart it is traditionally referred to as a flow process chart, as contrasted to operation process chart.

2.5.3 The analysis and action columns provide the means for developing an improved method. Considerations are to be given to the questions printed in the headings of the applicable columns. When any one of these questions suggests the possibility of improvement, a check mark is placed in that column and also in the appropriate action column. By means of this discipline, the development of an improved method is greatly facilitated.

2.5.4 When a series of activities or entries is repeated a number of times, these may be condensed into one line as shown on Figure 6(a) by the note bordered by wavy lines. The entries repeated are multiplied by the number of times and added to the sum of the individual entries in order to account for the total.

2.5.5 Figure 6(b) shows a proposed method of handling air freight that resulted from utilizing the check marks made in the analysis columns and the notes on Figure 6(a) suggesting possible improvements.

2.5.6 An example of cost analysis on a tabular process chart form is given in Figure 7. Features of this form are: the provision for showing both present and proposed methods; preprinted symbols; a summary showing cost data and savings; and more complete information under the identification heading. The reverse side is arranged to provide a cross section background for a sketch of a layout or flow diagram and basic information for identification.

2.5.7 When material is followed from the beginning to the end of a process, the unit being charted may change from time to time. When this occurs, it is important to show what the unit is at any point on the chart so that confusion will be avoided. In the illustration given, the chart shows the process of transforming an aluminum bar into relief valve bodies. The bars are loaded and unloaded singly, but are moved twenty at a time. At the third operation, each bar is machined and cut up to form fifty valve bodies. For all subsequent operations, one valve body is the unit, but the valve bodies are moved in quantities of one hundred or three hundred until they are packed. The unit then becomes twenty-five valve bodies contained in a packing case. This quantity information is entered in the spaces provided under that heading in the identification section of the chart.

2.5.8 It is customary to express all costs on the basis of the finished product. The cost unit may be one finished item, a dozen, or any number, being determined by the nature of the product. In any case, the allowed time information for operations, transportations, and inspections, which is to be recorded on the chart, should be given on the basis of the cost unit. If, for example, in the case given in Figure 7, it requires 0.0100 hr to load one bar into the truck, because one bar makes fifty valve bodies, the time charged per valve body will be $0.0100 \div 50 = 0.0002$ hr. Similarly, if it takes 0.2000 hr to move twenty bars 210 ft, the time charged per valve body will be $0.2000 \div (50 \times 20) = 0.0002$ hr. However, the time for delays and storages is not divided by the number of units in the bar or lot, for each unit is delayed or stored the full time. The same reasoning applies to recording distance moved. The distance the bar is moved is not divided by fifty because each unit within the bar must move the entire distance. By keeping all the time figures which directly affect cost on the basis of the same unit, confusion is avoided and all figures on the chart are directly comparable. The cost unit chosen is recorded on the

Plant ABC Project 34-7
By LFT With REX
Date 6/8 Sheet 1 of 1

Conversions for Charted Unit to End Unit		
Charted Unit	Size or Weight	Quantity per End Unit
Protector	2 lbs.	(End unit)
Carton (filled)	4½ lbs.	1 per 2 protectors
Formed piece	2 lbs.	1 per 1 protector
Blank	2 lbs.	1 per 1 protector
Steel Plate	65 lbs.	1 per 2.3 protector

Process Charted: Make door protectors from steel plates.

Starting Point Steel storage
Ending Point Finished Goods Storage

☒ Present or ☐ Proposed (Alt. # _____)

Description of Alternative _____

Quantity of End Unit per (time) _____
1380 protectors per day

Charted Unit and Units per Load	Activity Symbol	Description of Action	Weight of Load in lbs.	Number of Trips per Day	Distance in feet	Notes
1. Steel Plates	▽ ¹	Stacked on floor	—	—	—	
2. Steel Plates — 12	⇨ ¹	To Cutting on 4-wheel push-truck	780	5	280	
3. Steel Plate — One	①	Cut to size	—	—	—	Offal
4. Blank — One	⇨ ²	To form press on conveyor	2	1380	20	
5. Blank — One	②	Formed	—	—	—	
6. Formed Piece — 400	⇨ ³	To In-process Storage, pallet & lift truck	800	3.5	320	Hand-Powered low-lift truck
7. Formed Piece — 400	▽ ²	On pallet on floor	—	—	—	Sometimes moved to pallet rack with hi-lift truck
8. Formed Piece — 400	⇨ ⁴	To Grinding on pallet & lift truck	800	3.5	80	Hand-powered low-lift truck
9. Formed Piece — One	③	Ground to break all edges	—	—	—	
10. Protectors — 260	⇨ ⁵	To Packing by lift truck and pallet box	520	5.3	370	260 protectors per pallet box.
11. Protectors — Two	④	Packed in carton	—	—	—	Packing materials supplied in advance
12. Cartons — 140	⇨ ⁶	To F.G. Storage on pallet & lift truck	630	5	210	
13. Cartons — 140	▽ ³	Pallets with cartons stacked on floor	—	—	—	
14.						
15.						
Totals:		④⇨▽ ³	Total		1280	

FIG.5 PROCESS CHART – RAW MATERIAL TO FINISHED PRODUCT.

NO. _____

PAGE 1 OF 1

SUMMARY

	PRESENT		PROPOSED		DIFFERENCE	
	NO.	TIME	NO.	TIME	NO.	TIME
○ OPERATIONS	50	6.6				
◇ TRANSPORTATIONS	43	21.3				
□ INSPECTIONS	17	21.9				
◇ DELAYS	1	8.5				
▽ STORAGES	-	-				
DISTANCE TRAVELLED	1471	FT.		FT.		FT.

JOB **RECEIVE AIRFREIGHT PACKAGE AND BRING**

TO OUTGOING FREIGHT AREA

☒ MAN OR ☐ MATERIAL BAGGAGE HANDLER

CHART BEGINS AT RECEIVING DOCK

CHART ENDS OUTGOING FREIGHT AREA

CHARTED BY A. S DATE

[illegible]

FIG. 6(a) PRESENT METHOD — PERSON-TYPE FLOW PROCESS CHART UTILIZING PREPRINTED SYMBOLS AND ANALYSIS-ACTION COLUMNS

NO. _____
PAGE 1 OF 1

FLOW PROCESS CHART

JOB RECEIVE AIRFREIGHT PACKAGE AND BRING TO OUTGOING
FREIGHT AREA
☒ **MAN OR** ☐ **MATERIAL** BAGGAGE HANDLER
CHART BEGINS AT RECEIVING DOCK
CHART ENDS AT "OUTGOING FREIGHT" AREA
CHARTED BY A. S. DATE

[illegible]

11

IDENTIFICATION				FLOW PROCESS CHART										SUMMARY																																																																																	
SUBJECT CHARTED: RELIEF VALVE BODY DRAWING NO.: A-520652 PART NO.: 16150 POINT AT WHICH CHART BEGINS: RECEIPT OF REQUISITION FROM MACHINE SHOP POINT AT WHICH CHART ENDS: STORING OF FINISHED PRODUCT IN STOREROOM LOCATION: NEAR STOCK STOREROOM LOCATION: ASSEMBLY STOREROOM				CHART NO.: 1021 TYPE OF CHART: _____ SHEET NO.: 1 OF 1 SHEETS CHARTED BY: J. Smith DATE: 9 8 43 APPROVED BY: J. Jones DATE: 9 9 43				TOTAL YEARLY SAVING-DIRECT LABOR: \$2200 00 INSTALLATION COST OF PROPOSED METHOD: \$150 00 ESTIMATED NET SAVING-FIRST YEAR: \$2050 00										<table border="1" style="width:100%; border-collapse: collapse;"> <tr> <th colspan="2"></th> <th colspan="2">PRESENT METHOD</th> <th colspan="2">PROPOSED METHOD</th> <th colspan="2">DIFFERENCE</th> </tr> <tr> <td colspan="2">UNIT COST-DIRECT LABOR & INSP.</td> <td colspan="2">.300</td> <td colspan="2">.278</td> <td colspan="2">.022</td> </tr> <tr> <td colspan="2">DISTANCE TRAVELED IN FEET</td> <td colspan="2">7383</td> <td colspan="2">1843</td> <td colspan="2">5540</td> </tr> <tr> <td></td> <td>NO. TIME IN HRS.</td> <td>NO.</td> <td>TIME IN HRS.</td> <td>NO.</td> <td>TIME IN HRS.</td> <td>NO.</td> <td>TIME IN HRS.</td> </tr> <tr> <td>○ OPERATIONS</td> <td>8 .3750</td> <td>7</td> <td>.3064</td> <td>1</td> <td>.0175</td> <td></td> <td></td> </tr> <tr> <td>□ TRANSPORTATIONS</td> <td>9 .0085</td> <td>6</td> <td>.00222</td> <td>3</td> <td>.00628</td> <td></td> <td></td> </tr> <tr> <td>□ INSPECTIONS</td> <td>2 .0085</td> <td>1</td> <td></td> <td>1</td> <td>.0085</td> <td></td> <td></td> </tr> <tr> <td>□ DELAYS</td> <td>12 31.5</td> <td>8</td> <td>25.5</td> <td>4</td> <td>6.0</td> <td></td> <td></td> </tr> <tr> <td>▽ STORAGES</td> <td>2 1.08 C</td> <td>1</td> <td>.60 0</td> <td>1</td> <td>.38 0</td> <td></td> <td></td> </tr> </table>								PRESENT METHOD		PROPOSED METHOD		DIFFERENCE		UNIT COST-DIRECT LABOR & INSP.		.300		.278		.022		DISTANCE TRAVELED IN FEET		7383		1843		5540			NO. TIME IN HRS.	NO.	TIME IN HRS.	NO.	TIME IN HRS.	NO.	TIME IN HRS.	○ OPERATIONS	8 .3750	7	.3064	1	.0175			□ TRANSPORTATIONS	9 .0085	6	.00222	3	.00628			□ INSPECTIONS	2 .0085	1		1	.0085			□ DELAYS	12 31.5	8	25.5	4	6.0			▽ STORAGES	2 1.08 C	1	.60 0	1	.38 0		
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QUANTITY INFORMATION																																																																																															
1 BAR MAKES 50 BODIES																																																																																															
1 PACKING BOX HOLDS 25 BODIES																																																																																															
				YEARLY PRODUCTION 100,000 PIECES																																																																																											
				COST UNIT 1 VALVE BODY																																																																																											
PRESENT METHOD																																																																																															
QUANTITY UNIT CHARTED	SYMBOLS	DESCRIPTION OF EVENT	DIST MOVED IN FEET	UNIT OPER TIME IN HRS	UNIT TRANSP TIME IN HRS	UNIT INSPECT TIME IN HRS	DELAY TIME IN HRS	STORAGE TIME IN HRS																																																																																							
1 BAR	①	Bar loaded on truck upon receipt of requisition from machine shop (2 men)	10	.0002																																																																																											
20 BARS	②	Moved to #301 machine	210		.0002																																																																																										
1 BAR	③	Bar unloaded to bar stock rack near #301 machine (2 men)	10	.0002																																																																																											
	④	Bar waits for operation to begin					4.00																																																																																								
1 VALVE BODY	⑤	Drill, bore, tap, seat, file and cut off	8	.0550																																																																																											
	⑥	Await movement					4.00																																																																																								
300 VALVE BODIES	⑦	Moved to burring department	300		.0011																																																																																										
	⑧	Await burring operator					1.50																																																																																								
1 VALVE BODY	⑨	Burr	6	.0075																																																																																											
	⑩	Await movement					2.00																																																																																								
300 VALVE BODIES	⑪	Moved to drill press in machine shop	320		.0011																																																																																										
	⑫	Await drilling operator					2.00																																																																																								
1 VALVE BODY	⑬	Drill and countersink 8 holes		.0480																																																																																											
	⑭	Await movement					4.00																																																																																								
300 VALVE BODIES	⑮	Moved to inspection department	100		.0001																																																																																										
	⑯	Await inspector					1.50																																																																																								
1 VALVE BODY	⑰	Inspect	8		.0085																																																																																										
	⑱	Await movement					2.00																																																																																								
300 VALVE BODIES	⑲	Moved to storeroom 2	3009		.0030																																																																																										
	⑳	Stored until requisitioned by detail department					48.0																																																																																								
300 VALVE BODIES	㉑	Moved to seat lapping machine	2550		.0025																																																																																										
	㉒	Await operator					1.50																																																																																								
1 VALVE BODY	㉓	Lap, seat, and test	6	.1700																																																																																											
	㉔	Await movement					2.00																																																																																								
100 VALVE BODIES	㉕	Moved to paint booth	400		.0004																																																																																										
	㉖	Await painter					4.00																																																																																								
VALVE BODY	㉗	Mask, prime, paint, dry and unmask	10	.0350																																																																																											
100 VALVE BODIES	㉘	Carried to packer by painter	125		.0001																																																																																										
	㉙	Await packing					3.00																																																																																								
1 VALVE BODY	㉚	Pack in box	12	.0100																																																																																											
BOX 25 VALVE BODIES	㉛	Sent by conveyor to assembly department storeroom	300																																																																																												
	㉜	Storage until requisitioned					60.0																																																																																								
PROPOSED METHOD																																																																																															
QUANTITY UNIT CHARTED	SYMBOLS	DESCRIPTION OF EVENT	DIST MOVED IN FEET	UNIT OPER TIME IN HRS	UNIT TRANSP TIME IN HRS	UNIT INSPECT TIME IN HRS	DELAY TIME IN HRS	STORAGE TIME IN HRS																																																																																							
1 BAR	①	Bar loaded on truck upon receipt of requisition from machine shop (2 men)	10	.0002																																																																																											
20 BARS	②	Moved to #301 machine	210		.0002																																																																																										
1 BAR	③	Bar unloaded to bar stock rack near #301 machine	10	.0002																																																																																											
	④	Bar waits for operation to begin					4.00																																																																																								
1 VALVE BODY	⑤	Drill, bore, tap, seat, file and cut off	8	.0550																																																																																											
	⑥	Await drill press operator					2.00																																																																																								
100 VALVE BODIES	⑦	Moved to drill press by operator	20		.0002																																																																																										
1 VALVE BODY	⑧	Drill 8 holes	8	.0350																																																																																											
	⑨	Await movement					2.00																																																																																								
300 VALVE BODIES	⑩	Moved to burring department	300		.0011																																																																																										
	⑪	Await burring operator					1.50																																																																																								
1 VALVE BODY	⑫	Burr	6	.0100																																																																																											
	⑬	Await movement					2.00																																																																																								
300 VALVE BODIES	⑭	Moved to seat lapping machine-detail department	550		.0005																																																																																										
	⑮	Await operator					6.00																																																																																								
1 VALVE BODY	⑯	Lap, seat, test and inspect	6	.1700																																																																																											
	⑰	Await movement					2.00																																																																																								
100 VALVE BODIES	⑱	Moved to paint booth	400		.0004																																																																																										
	㉑	Await painter																																																																																													
1 VALVE BODY	㉒	Mask, prime, paint, dry, unmask, pack in box	15	.0380			6.00																																																																																								
BOX 25 VALVE BODIES	㉓	Sent by conveyor to assembly department storeroom	425																																																																																												
	㉔						60.0																																																																																								

FIG. 7 FLOW PROCESS CHART WITH PREPRINTED SYMBOLS SHOWING PRESENT AND PROPOSED METHODS WITH A SUMMARY OF COST SAVINGS

chart to complete the necessary preliminary information.

2.5.9 The chart proper is begun by recording in the first column under the head of "Present Method" the quantity unit being charted at the beginning of the process. A brief description of the event which first occurs is entered in the third column. In Figure 7 this is "Bar loaded on truck upon receipt or requisition from machine shop (2 men)". This is classed as an operation. It is the first operation which has occurred, so the numeral 1 is placed within the operation symbol in column two. The information concerning this first event is completed by recording the total distance the bar is moved and the unit time for moving it.

2.5.10 When the charting of the first event is completed, the information regarding the second event is entered. This is repeated until the process has been completely charted. All operations, transportations, inspections, delays, and storages are numbered serially in the order in which they occur, with each type of activity having its own numerical series. To complete the chart, it is the usual practice to join all used symbols with short straight lines so that the activity sequence of the process will stand out clearly. A study of Figure 7 will show the conventions followed in constructing this type of process chart.

2.5.11 When writing the description of events charted, it is preferable to use the passive voice when material is being followed. This is logical since the material is the object of all the actions taking place and cannot of itself initiate action. It further helps the chart maker to keep his attention focused on the material being followed, instead of becoming sidetracked by following an operator or the individual involved in the move.

2.5.12 When writing the description of events on a person-type process chart, the active voice is used, because the person who is being followed is the one who initiates the action.

2.5.13 Whenever an activity outside of the scope of the investigation occurs, it is the convention to break the vertical process line (or the connecting line) at the point where the interruption occurs by drawing two wavy horizontal lines about $1\frac{1}{2}$ in. (40 mm) long and $\frac{1}{4}$ in. (5 mm) apart, centered with respect to the vertical (or connecting) line. An activity outside the scope of the investigation is an operation, transportation, inspection delay,

delay, shortage, or series of these which for any reason the investigator considers unnecessary or impractical to analyze during the current study.

2.5.14 The arrow which is used for the transportation symbol may be drawn as a straight line with arrow head as_ when not preprinted or drawn with the aid of a template. The symbol may be given additional meaning by changing its direction. When the arrow points to the right, the material is represented as progressing in the proper direction. When the arrow points to the left, backtracking is indicated. Upward movement of the material is indicated by pointing the arrow upward, and downward movement by pointing the arrow downward.

2.6 Use of A Summary Form

To bring out clearly the difference between the present and the proposed methods, a summary form is provided in the upper right hand corner of Figure 7. The summary provides space for recording the total yearly labor saving, the cost of putting the proposed method into effect, and the estimated net saving for the first year. This information is supported by a summary of the detailed changes in terms of unit cost, distance traveled, and number and time of operations, transportations, inspections, delays, and storages under the present and proposed methods. No direct monetary savings are usually shown as resulting from reductions in distance moved or storage or delay time, as it is difficult to measure accurately savings emanating from these sources. Experience, of course, indicates that when distances moved or storage or delay times are decreased, the operation of the plant is more effective, so the results accomplished in this direction are recorded in the summary.

2.7 Conclusion

2.7.1 A process chart is a schematic or tabular representation of events and information pertaining thereto occurring during a series of actions or operations. Its purpose is to present a picture of a given process so clearly that an understanding of its every step will be gained by all who study the chart.

2.7.2 The principles and practices described herein have been selected from those in use, because they appear to give a clear, practical portrayal of the kind of activities with which process charts are most commonly used. Although these principles and practices will probably apply satisfactorily to the great majority of processes charted, it is recognized that there may

be cases in which it will be felt that the process will be made clearer if practices not covered by the standard procedure are introduced.

2.7.3 The examples shown in this edition have been drawn from industrial applications. It should be noted, however, that the process chart is admirably suited to the study of paperwork systems and procedures. For such analyses, the usual chart is made to portray the flow of each copy of a multicopy form.

Then, the chart for each copy is redrawn on paper of sufficient size, leaving spaces for noting actions taken on other papers and records affected.

2.7.4 It is recognized that departures from standard practice may be permissible if clearness of presentation is gained. At the same time, in the interest of standardization it is recommended that the principles and practices described under the head of Major Conventions be adhered to whenever possible.

AMERICAN NATIONAL STANDARDS OF PARTICULAR INTEREST TO DESIGNERS, ARCHITECTS AND DRAFTSMEN

TITLE OF STANDARD

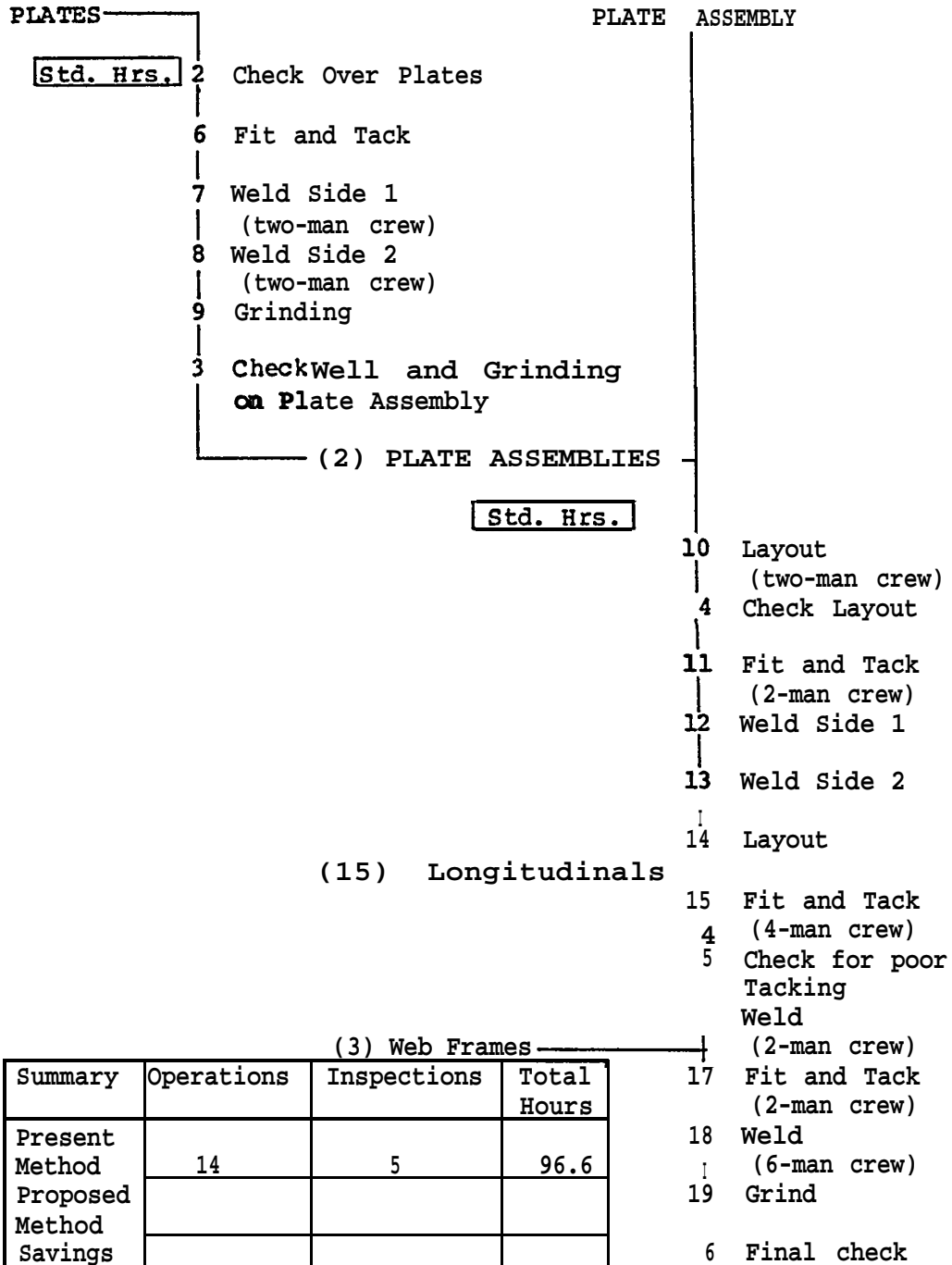
Abbreviations	Y1.1-1972
American National Standard Drafting Practices	
Size and Format.	Y14.1-1975
Line Conventions and Lettering.	Y14.2M-1979
Multi and Sectional View Drawings.	Y14.3-1975
Pictorial Drawing	Y14.4-1957
Dimensioning and Tolerancing for Engineering Drawing	Y14.5-1973
Screw Threads.	Y14.6-1978
Gears and Splines	
Spur, Helical and Racks	Y14.7.1-1971
Bevel and Hypoid	Y14.7.2-1978
Forgings	Y14.9-1958
Metal Stampings.	Y14.10-1959
Electrical and Electronic Diagram.	Y14.15-1966 (Reaffirmed 1973)
Interconnection Diagrams.	Y14.15a-1971
Fluid Power Diagrams	Y14.17-1966 (Reaffirmed 1974)
Computer-Aided Preparation of Product Definition Data Dictionary of Terms	Y14.26.3-1975
Digital Representation of Physical Object Shapes.	ASME TR #1
Guideline — User Instructions.	ASME TR #2
Guideline — Design Requirements	ASMT TR #3
Ground Vehicle Drawing Practices	In Preparation
Chassis Frames	Y14.32.1-1974
Surface Texture Symbols	Y14.36-1978
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Process Charts	Y15.3M-1979
Graphic Symbols for:	
Electrical and Electronics Diagrams.	Y32.2-1975
Plumbing.	Y32.4-1977
Use on Railroad Maps and Profiles	Y32.7-1972 (R1979)
Fluid Power Diagrams	Y32.10-1967 (Reaffirmed 1974)
Process Flow Diagrams in Petroleum and Chemical Industries.	Y32.11-1961
Mechanical and Acoustical Element as Used in Schematic Diagrams	Y32.18-1972 (Reaffirmed 1978)
Pipe Fittings, Valves and Piping.	Z32.2.3-1949 (Reaffirmed 1953)
Heating, Ventilating and Air Conditioning.	Z32.2.4-1949 (Reaffirmed 1953)
Heat-Power Apparatus	Z32.2.6-1950 (Reaffirmed 1956)
Letter Symbols for:	
Glossary of Terms Concerning Letter Symbols	Y10.1-1972
Hydraulics	Y10.2-1958
Quantities Used in Mechanics for Solid Bodies	Y10.3-1968
Heat and Thermodynamics	Y10.4-1957
Quantities Used in Electrical Science and Electrical Engineering	Y10.5-1968
Aeronautical Sciences	Y10.7-1954
Structural Analysis	Y10.8-1962
Meteorology	Y10.10-1953 (Reaffirmed 1973)
Acoustics.	Y10.11-1953 (Reaffirmed 1959)
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Guide for Selecting Greek Letters Used as Letter Symbols	
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Illuminating Engineering	Y10.18-1967 (Reaffirmed 1977)
Mathematical Signs and Symbols for Use in Physical Sciences and Technology	Y10.20-1975

*The ASME Publications Catalog shows a complete list of all Standards published by the Society.
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TYPICAL PANEL ASSEMBLY OPERATION

The operation process chart here indicates those activities for flat panel assemblies starting at the panel line.





TYPICAL PANEL ASSEMBLY

The following is a detailed description of the steps required for the manufacturing of a typical panel assembly. The flow process chart symbols and distances have been omitted.

Distance (in ft.)	Symbol	Description
	1	Raw plates stored in a steelyard. A 15-ton cantilever gantry crane (magnetic) moves the plate from the steel yard to a conveyor system that feeds the wheel abrator.
	2	Shot blast plate to remove mill scale (Note: plate is not primed at this time.)
	1	Check for mill scale and rust. Move plate on conveyor to collocator car. The collocator car delivers the plate into the burning table area.
	3	Plate is held on the collocator track bed until needed. Move plate from storage to the burning machine with a 10-ton bridge crane (magnetic).
	4	Plate is cut to correct shape and layout coordinates are marked on the plate, both numerically controlled. Move plate to holding area using a 10-ton bridge crane (magnetic).
	5	Plate is held for next operation.
	2	Check for correct edge preparation. Plate is moved to panel line Station 1 using a 10-ton bridge crane (magnetic).



Distance (in ft.)	Symbol	Description
	6	Panel line Station 1: two or more plates are aligned and tacked together to form a plate assembly. Plate assembly is moved to Station 2-- using panel line power chain.
	7	Panel line Station 2: weld. Weld assembly on Side 1. Plate assembly is moved to Station 3 using panel line power rollers.
	8	Panel line Station 3: turn plate assembly over (180°) with a Whirley crane, and weld assembly on Side 2.
	9	Grind off weld splatter.
	3	Check plate assembly for weld splatter removal. Plate assembly is moved to Station 4 using panel line power chain. Panel line Station 4: hold for removal from panel line. Move plate assembly to platen using a Whirley crane.
	10	One or two plate assemblies are laid out (pitched) for alignment.
	4	Check layout alignment.
	11	Two or more plate assemblies or plates are aligned and tacked together to form a panel assembly.
	12	Weld, assembly together on Side 1.
	13	Turn panel assembly over with a Whirley crane and weld assembly on Side 2.
	14	Layout panel assembly for longitudinals, stiffeners, and web frames.



Distance (in ft.)	Symbol	Description
	15	Fit and tack longitudinals or stiffeners to panel assembly, using 10-ton semi gantry crane to position longitudinals, which are staged on platen for this operation.
	5	Check assembly position before welding.
	16	Weld longitudinals or stiffeners to panel assembly.
	17	Fit and tack web frames to panel assembly, using a 10-ton semi gantry crane to position web frames. Web frames are staged on platen for this operation.
	18	Weld web frames to panel assembly. Move panel assembly from platen to gritblast using a Whirley crane.
	19	Remove weld splatter and grind off all sharp edges.
	20	Gritblast panel assembly.
	6	Check gritblast results. Move panel assembly gritblast to painting area using a Whirley crane.
	20	Paint panel assembly (primer). Panel assembly is moved from paint area to storage on the erection site.
	10	Stage panel assembly for erection.
	22	Panel assembly becomes part of the ship.



TRANSPORTATION DISTANCES

<u>Transportation Number</u>	<u>Distance in Feet</u>
1	85
2	390
3	50
4	65
5	255
6	50
7	50
8	30
9	890
10	1,250
11	730
12	860
13	Use your own
14	estimate if
15	necessary



LINEAR RESPONSIBILITY CHARTING (LRC)

Clear up organizational confusion through a technique called linear responsibility charting or LRC. LRC provides a way to pin down who does what about what, and who is really responsible. It aids in eliminating job duplication, and reducing uneven workloads. Linear responsibility charting (LRC) is fast, cheap, and simple enough to be used in the smallest shipyard.

LRC can make quick common sense out of stacks of organizational paperwork. The typical shipyard uses charts and graphs trying to clarify how it "works." Organization charts are familiar to all. Job descriptions have been used to assign specific tasks, and overall work flow charts usually are stuffed into the thick organizational procedure manuals. It is a small wonder that the results are usually outdated, somewhat vague, and and possibly conflicting. The chances are excellent that the charts do not cover everything. For the new man who must wade through the committees, the unofficial systems, the paperwork, and the company diagrams, it can be very difficult just to find out who does what.

With LRC, it is possible to present the facts on one small chart that were attempted to be presented in the standard organization manuals. There are added features as well. Charts not only show who does what, but also who the worker reports to, consults with, the kind of workload the worker is carrying, and how the worker's job fits in with others. LRC can help eliminate responsibility arguments and cut through the red tape of seeking too many approvals.

LRC charts are constructed with the job titles or the organization units listed across the top of the chart. The specific responsibilities or duties are listed down the left side. Where the two categories meet, a code is used to show if that person performs the work, supervises it, or influences it; in general, what that person does in regard to certain responsibilities. In this way, the LRC chart shows interrelated job responsibilities. It defines exactly how each job is done and how each man fits into the organizational structure. (Refer to Figure 2 in this section to see a completed LRC chart.)

The vertical column under a person's job shows every contribution to be made by the person with that job. For each of the tasks listed on the left side of the chart, a horizontal column shows the division of responsibility for the task listed. The LRC chart shows a quick, simple, management roadmap. It is easy to follow and easy to update.

How is LRC used? LRC was originally developed as a means of organizational analysis, but its versatility caused it to spread into other areas. LRC is used in organizations today to help cut the cost of overhead, discover needs for training, show up areas of responsibility weaknesses, eliminate bottlenecks, smooth out workloads, discover empire building and overlapping areas, simplify paperwork, and aid in decision-making.

LRC also help implement the one-time organizational change such as the decentralization of authority or improvement of procedures.



LRC charts can be put to additional use by using transparent overlays to show individual efficiency. The overlays show the breakdown of specific jobs according to the percent of effort spent on supervisory, routine, or consulting types of activities. Overlays also can be used for comparing present with proposed procedures by adding costs, man-hours, or the number of steps involved in performing certain tasks.

In-preparing linear responsibility charts, keep in mind that the preparation of the chart is usually more important and brings about more improvement than actually using the chart after it has been prepared. It is the preparation phase of the chart that shows up the uneven workloads, the confusion, and other poor organization practices. The preparation of an LRC chart is a precise and time-consuming job. Make a decision about exactly what you are trying to do. Remember that functions are usually performed by organizational units, but work is performed by people. Use separate charts for each and limit the scope of the chart. In most companies, it would be unwise to mix clerks and executives in the same chart since this would involve too many unnecessary and distracting details. Keep in mind also what the chart is designed to show. You may want to show an entire function such as industrial engineering or a procedure such as providing tools, materials, and methods for a new class of ship. Keep each chart simple so it is easy to use.

Chart language must be uniform. Imprecise wording on the chart will ruin its effectiveness. Words such as "conduct" or "administrate" can have different meanings to different people. Job titles can be obtained from conventional company sources, but their functions and how they are performed will have to be decided by interviews with each of the people or the units involved. It is the job of the person conducting the interview to pin down what goes on in fact, not what is supposed to happen; people have a natural tendency to be impressed with the importance of their own jobs.

Interviewers must be sure what they are told to correct. They must interview people in small related groups. This way they act as checks and balances on each other, and will challenge immediately any statement that conflicts with their own concepts of the job. Questions must be asked to find out who really calls the shots, or does the actual work, or takes the responsibility. Usually conflicts will be resolved by the general agreement that only one person can have the responsibility.

The interviewer often will hear answers such as "we administer that," or "we expedite this." Keep probing until the specific activity is revealed. Find out who does the work or who takes the action. This worker is the key to that particular task. Whoever the worker reports to or checks with and who the worker gets information from can then be related to the key person.

Each work description must be boiled down to one crisp clear line. Since the idea of the LRC chart is to find out what people do and not how important they are, begin each task with an active verb. For example: approve purchase order, issue route sheet, estimate labor costs, determine operation sequence. Each item must have a well-understood meaning.



When this phase has been completed, the appropriate codes can be added to the chart. There must be at least one "work is done" code on each horizontal line, although other codes may be used.

In the following figures, Figure 1 shows the codes that are used in constructing an LRC chart with their definitions, and Figure 2 shows a completed LRC chart.



Figure 1

DEFINITIONS OF SYMBOLS FOR LINEAR RESPONSIBILITY CHARTING

- 1 Work Is Done. *The activity-is actually performed by the individual filling the position.*
- 2 General Supervision. Covers the important aspects of general planning, delegation, and control. No detailed supervision.
- 3 Direct Supervision Over Work Done. Close supervision, usually covering the details of work performed by a subordinate. May involve "hour-to-hour" or "day-to-day" supervision.
- 4 Supervision with Coordination. Applies to supervising several individuals working on the same activity, where a unified approach is necessary. Can be compared with supervision exercised by the chairman of a committee or a board chairman.
- 5 Decision on Points Specially Submitted. Applies to decisions on special points by a person other than the one responsible for the activity. Most frequent examples include:
 - decision on specific technical points when a specialist is best qualified to make it
 - decision on minor points delegated by a manager to a subordinate
 - decision on major points retained by the manager. The rest is delegated to a subordinate.
- 6 Person Must Be Consulted. Before a decision is taken, the individuals whose jobs are marked with this symbol must be consulted.
- 7 Person Must Be Notified. The individuals whose jobs are marked with this symbol must be advised -- verbally or in writing.
- 8 Person May Be Called In for Exchange of Views. The emphasis is on may. There is no obligation to consult, or rights of consultation.



Figure 2

LINEAR RESPONSIBILITY CHART

Methods/Cost

Improvement Program

Job Title or Position										
Pres.	Exec. V.P.	V.P. Mgr. Serv.	Dir. I.E.	V.P. Mgr.	Mfg. Mgr.	Chief I.E.	Ind. Eng.			

Seq.	Area of Responsibility or Duties	A	B	c	D	E	F	G	H	I	J	K
1	Review potential cost imp.	7	2	1	6		6	6				
2	Evolve specific imp. projects			7	1	2	3	1	8			
3	Select projects to implement		5	7	3	2	1	3	8			
4	Reconcile differences of opinion		4	3	1	3	1	1				
5	Initiate project/estab. schedule			8	1	4	3	1				
6	Implement project				7			3	1			
7	Control at yard level			7	7		3	1				
8	Control at top mgmt. level		7	3	1		7					
9	Take remedial action if lagging		2	6	6	3	1	8	8			
10	Reconcile opinions on rem. action		4	1	6	1	1	8	8			

Legend

Definition	No.	Definition	No.
Work Is Done	1	Decision on Points Submitted	5
General Supervision	2	Person, Must Be Consulted	6
Direct Supervision over Work Done	3	Person Must Be Notified	7
Supervision with Coordination	4	May Require Exchange of Views	8



LINEAR RESPONSIBILITY CHART

		Job Title or Position										
Seq.	Area of Responsibility or Duties	A	B	c	D	E	F	G	H	I	J	K

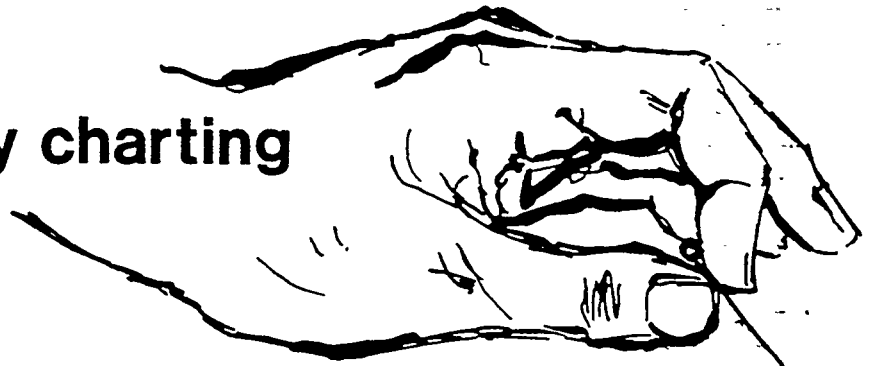
Legend

Definition	No.	Definition	No.
Work Is Done	1	Decision on Points Submitted	
General Supervision	2	Person Must Be Consulted	0
Direct Supervision over Work Done	3	Person Must Be Notified	1
Supervision with Coordination	4	May Require Exchange of Views	

Here is a tool that is used in organization analysis to help cut overhead costs, uncover training needs, spotlight areas of responsibility weaknesses, break bottlenecks, balance work loads, discover empire building, and simplify paperwork control and decision making.

DONALD W. BARNES, Serge A. Birn Company, Louisville, Kentucky

Linear responsibility charting



There is a fast way to clear up organizational confusion. The technique is called Linear Responsibility Charting (LRC). LRC provides a way to pin down who does what about what, and who's really responsible. It also aids in cutting down organizational confusion, in eliminating job duplication, and reducing uneven work loads. Another redeeming feature of LRC is its ability to cut through red tape. Linear responsibility charting is fast, cheap, and simple enough to be used in the smallest plant.

LRC can make quick common sense out of stacks of organization paper work. The typical company will use charts, graphs, and what have you, trying to clarify how they "work." Organization charts are familiar to all. Job descriptions have been used to assign specific tasks, and overall work flow charts also are usually stuffed into the thick organizational procedure manuals. It is a small wonder that the results are usually outdated, somewhat vague, and possibly conflicting. The chances are excellent that they still do not cover everything. For the new man (who must wade through the committees, the unofficial systems, the paper work, company diagrams, and what have you) it can be very difficult just to find out who does what!

LRC cuts through this mountain of paper work. It is possible, on one small chart, to present the facts that were attempted to be presented in the standard organization manuals. There are added features as well. The charts not only show who does what, but also who he reports

to, consults with, the kind of work load he is carrying, and how his job fits in with those of all others. It can help eliminate responsibility arguments and cut through the red tape of getting too many approvals.

Construction

Linear Responsibility Charts are constructed with the job titles or the organization units listed across the top of the chart. The specific functions or duties are listed down the left side. Where the two axes meet, a symbol is used to show if that person performs the work, supervises it, influences it, or what. In this way, the chart shows interrelated job responsibilities. It defines exactly how each job is done and how each man fits into the organization structure. It shows who gets into the act and why.

Figure 1 shows a completed linear responsibility chart. Notice that the vertical column under a particular person's job shows every contribution that is to be made by the person with that job. For each of the tasks listed on the left side of the chart, a horizontal column shows the division of responsibility for the task listed. In other words, the chart shows a quick, simple, management roadmap. It's easy to follow and easy to update.

Figure 2 shows the symbols that are used in constructing a linear responsibility chart, including a definition of each symbol.

use

How is LRC used? LRC was orig-

inally developed as a means of organizational analysis, but its versatility caused it to spread into other areas. LRC is used in organizations today to help cut the cost of overhead, discover needs for training, show up areas of responsibility weaknesses, break bottlenecks, smooth out work loads, discover empire building and overlapping areas, and simplify paper work control and decision making.

LRC has also been found useful in helping to implement the one time organizational change, such as the decentralization of authority, or improvement of procedures.

Linear responsibility charts can be put to additional use by using transparent overlays to show individual efficiency. The overlays are used to break down specific jobs according to the percent of effort spent on supervisory, routine, or consulting types of activities. It can also be used for comparing present with proposed procedures by adding costs, man-hours, or the number of steps involved in performing certain tasks. LRC is very adaptable and precautions are usually necessary, once LRC has been introduced, to keep down the number of incompatible charts that could be used. There is a tendency to record all of the old confusion in a new format.

Preparation

In preparing linear responsibility charts, one must keep in mind that the preparation of the chart is usually more important, and brings about more improvement than ac-

tually using the charts after they have been prepared. It is the preparation phase of the chart that shows up the uneven work loads, the confusion, and other poor organization practices. The finished chart is often anticlimatic.

The preparation of a linear responsibility chart is a precise and time-consuming job. The first step is to make a reasonable decision about exactly what you are trying to do. There is a tendency to attempt to start off too big at first. Remember that functions are usually performed by organizational units, but work is performed by people. Use separate charts for each unit and limit the scope of each chart. In most companies, it would be wise to mix clerks and executives in the same chart since this would involve too many unnecessary and distracting details. Keep in mind also what the chart is designed to show. You may want to show an entire function, such as industrial engineering, or a procedure, such as providing tools, rates, and methods for a new product line. The main idea is to keep each chart simple so that it's easy to use.

Chart language must be uniform. Wrong wording on the chart will ruin the effectiveness of it. Words such as "conduct" or "administrate" can have very different meanings to different people. Job titles can be obtained from conventional company sources, but their functions and how they are performed will have to be decided by way of interviews with each of the people or units involved. It is the job of the person conducting the interview to pin down what goes on *in fact*, not what is *supposed* to happen. This is not as easy as it sounds. People have a natural tendency to be impressed with the importance of their own jobs.

The interviewer must also be sure that what he is told checks out. The helpful way of doing this is to interview people in small related groups. This way they can act as checks and balances on each other and will challenge immediately any statement that conflicts with their own concepts of the job. Questions at this point must be asked to find out who really calls the shots, who does the actual work, or takes the responsibility from that point. Usually the conflicts will be resolved.

Many times the interviewer will

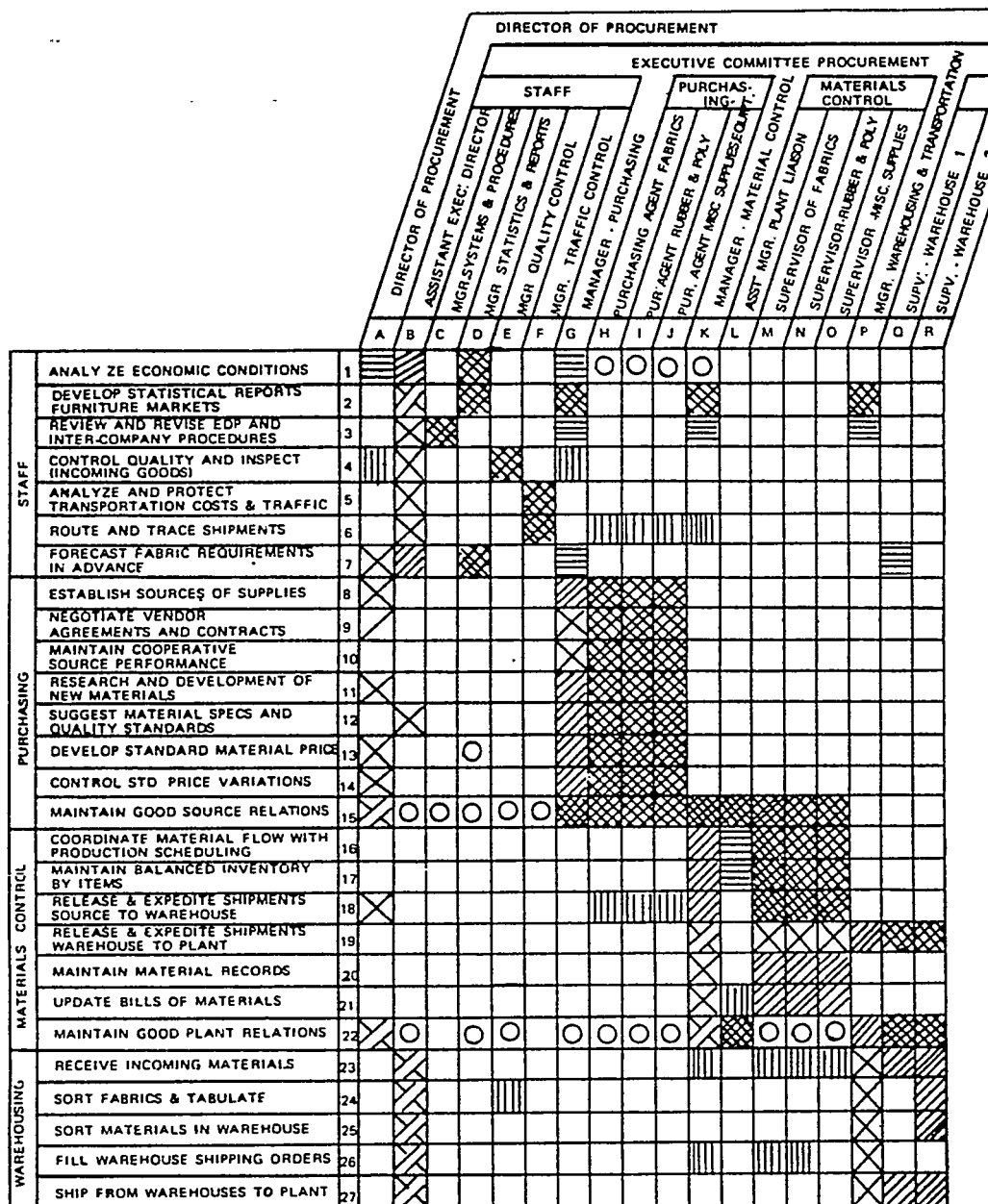


Figure 1. Example linear responsibility chart, a procurement division.

get answers such as "we administer that," or "we expedite this." But he must keep probing until he breaks it down to the specific activity itself. He must find out *who* does the work or *who* takes the action. This person is the key to that particular task. Whoever he reports to or checks with, and who he gets his information from can then be related to that one person.

Each work description must be boiled down to one crisp, clear line. Since the idea of linear responsibility charting is to find out what people do and not how important they are, each task should begin with an active verb. For example: *approve purchase order, issue route sheet, estimate labor costs, determine operation sequence*. Each item must have a meaning that is easily understood.

When this phase has been completed, the appropriate symbols can be added to the chart. There must

at least one "work is done" symbol on each horizontal line; other symbols may or may not be used on the same line.

If you find a real need to clear up organizational confusion or cut through red tape, you might consider using the techniques presented here. Linear responsibility charts can make common sense out of stacks of paper work. ■



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Before joining Serge A. Birn, he worked as an industrial engineer with Sunbeam Electronics, Fort Lauderdale, and as a training coordinator for Maynard Research Council, Pittsburgh.

Mr. Barnes is a graduate of the production management program at Pennsylvania State University, and is a licensed MTM instructor. He is a senior member of AIIE.



1. WORK IS DONE - The activity is actually performed by the individual filling the position.



2. GENERAL SUPERVISION - Covers the important aspects of general planning, delegation, and control. No detailed supervision.



3. DIRECT SUPERVISION OVER WORK DONE - Close supervision, usually covering the details of work performed by a subordinate. May involve "hour-to-hour" or "day-to-day" supervision.



4. SUPERVISION WITH COORDINATION - Applies to supervising several individuals working on the same activity, where a unified approach is necessary. Can be compared with supervision exercised by the chairman of a committee or a board chairman.



5. DECISION ON POINTS SPECIALLY SUBMITTED - Applies to decisions on special points, by a person other than the one responsible for the activity. Most frequent examples are:

- decision on specific technical points when a specialist is best qualified to make it,
- decision on points delegated by a manager to a subordinate,
- decision on major retained by the manager. The rest is delegated to a subordinate.



6. PERSON MUST BE CONSULTED - Before a decision is taken, the individuals whose jobs are marked with this symbol MUST be consulted. His opinion must be heard, though it need not be followed.



7. PERSON MUST BE NOTIFIED - The individuals whose jobs are marked with this symbol MUST be advised -- verbally or in writing.



8. PERSON MAY BE CALLED IN FOR EXCHANGE OF VIEWS - The emphasis is on "may". There is no obligation to consult, or right of consultation.

Figure 2. Standard symbols used in linear responsibility charting.



Section V Record and Measure the Time of an Operation

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WORK MEASUREMENT TECHNIQUES

"Work measurement is the application of systematic techniques to determine the work content of a defined task and the corresponding time required for its completion by a qualified worker. " (1) There are various techniques that have been used for work measurement, such as the use of historical data, estimates, stopwatch time studies, predetermined times, standard data, work sampling, and mathematical techniques. The three predominant methods for determining engineered work standards are time studies, predetermined motion and time systems (PMTS), and standard data. These techniques are primarily developed for work at a specific company. As a result, most of the specific standards and PMTS developed are proprietary and are usually not available. However, some of the standards and specific PMTS are available through the company or as association that developed them. The best source of information would be from that association or company. (1)

Listed below are some frequently used work measurement techniques, and a description of each.

Science Management Corporation
WOFAC Division
P. O. Box 6800
1011 Route 22
Bridgewater, NJ 08807
(201) 685-9000
Contact: Jim McGurk

1. DETAILED WORK-FACTOR developed from motion time studies using stopwatches, phototimers, films, and fast film snapshots
2. MENTO-FACIOR SYSTEM: developed to determine the time required for mental processes such as those involved in decision-making
3. READY WORK-FACTOR uses simplified Detailed Work-Factor time values
4. BRIEF WORK-FACTOR: simplified system, developed for measuring nonrepetitive work
5. WOCOM: computerized system using detailed and Ready Work-Factor and MTM(1)

MTM Association
16-01 Broadway
Fair Lawn, NJ 07410
(201) 791-7720
James P. O'Brien, Executive Director

Methods Time Measurement Systems (MTM)

1. MTM-1 : "MTM-1 is a procedure which analyzes any manual operation or method into the basic motions required to perform it and assigns to each motion a predetermined time standard which is determined by the nature of the motion and the



conditions under which it is made. . .The MTM-1 system consists of seven action categories containing 24 basic hand, arm, eye and body motions." (2)

2. MTM-2: second level: twice the speed of analysis of MTM-1 but lower precision
3. MTM-3: third level, seven times the speed of analysis of MTM-1, used where less detailed methods description is required and where reduced precision can be tolerated
4. MTM M-GPD: (General Purpose Data): functional and generic, uses second level pertaining to use of hand tools and third level for clamping and vising
5. MTM-C: functional, for use with clerical systems, on two levels--second and third
6. MTM-V: functional, for machine tool users
7. MTM-M: used with assembly under stereoscopic microscopes
8. 4M (Micro-Matic Methods and Measurement Systems): computerized MTM-1
9. ADAM (Automatic Data Application and Maintenance): computerized MTM developed for desktop computers
 - ADAM-2: computerized MTM-2
 - ADAM-C: computerized MTM-C
 - ADAM-V: computerized MTM-V (1)

MEK and UAS High order systems for small lot/high labor content jobs.

MTM ASSOCIATION OFFERS BROCHURES AND SEMINARS ON THEIR SYSTEMS

Walter Erwin
Industrial Engineering Services, Inc.
Route 7, Box 289
Rock Creek Road
New Bern, NC 28560
(919) 637-2471

Keith Burnett
Management Training Australia
The Vintage, Unit 11
281 Sussex Street
Sydney 2000
AUSTRALIA

1. MODAPTS (Modular Arrangement of PTS): second level, and the basic unit is simple finger movement
2. Office MODAPTS - for clerical standard data



3. Transit MODAPTS - for warehousing and materials handling standard data (1)

Serge A. Birn Co.
1049 Bardstown Road
P. o. Box 4155
Louisville, KY 40204
(502) 451-6640
Contact: Harold Nance

1. Master Standard Data (l&SD): second level, MTM-1 data based on manually controlled operations where production was less than 100,000 units\yr, since the operator would lose most of skill in between runs

2. Master Clerical. Data (MCD): a set of standard data developed from MTM systems dealing with clerical functions (1)

3. MCD-MOD II: Ccomputerized MCD. "The software will handle any work measurement approach with a specific code for each motion or element. It is written in standard COBOL using Direct and Indexed files and will run on a Mainframe or IBM Personal Computer. It operates on-line even though the illustrations utilize a batch mode form. " (3)

SERGE A. BIRN HAS A TRAINING SCHOOL IN CINCINNATI FOR MTM, MSD, MCD, MOTIVATION-PRODUCTIVITY , TIME STUDY, METHODS ENGINEERING, AND SUPERVISORY IMPROVEMENT.

H.B. Maynard & Co.
235-T Alpha Drive
Pittsburgh, PA 15238
(412) 963-8100

CONTACTS FOR INFORMATION

- A. Ken Merino (computers)
- B. Kjell Zandin (computer cost and estimate)

1. MOST (Maynard Operation Sequence Technique): based on MTM-1 and MTM-2, consistently repeated sequences of motions are modified and reduced in number

2. Mini MOST: designed to measure identical, short-cycle operations, concentrates on one aspect of the work spectrum

3. Maxi MOST: designed for lag-cycle heavy assembly or machining operations

74. Universal Maintenance standards - practical standards which act as guidelines for a worker's performance

THEY ALSO HAVE MOST COMPUTER SYSTEMS , AND MI CROMOST ESPECIALLY DESIGNED FOR MICROCOMPUTER . (4)



Robert E. Nolan Co. , Inc.
90 Hopmeadow Street
Sims bury, CT 06070
(203) 658-1941
Contact: Robert E. Nolan, President

1. Advanced Office Controls (AOC): "AOC is a third generation predetermined time system. AOC is based on Methods-Time Measurement (MTM), the world's most widely used first generation predetermined time system. AOC is used to analyze all levels of office activity, and to accurately and economically develop standards. These standards are used to monitor employee effectiveness, analyze processing systems, develop manpower budgets, and cost and price products and services. " (5)
2. Automated AOC: "Auto-Aoc is a complete package of computer hardware and software. " Auto AOC produces Task Outline, Task Analysis, and Task Summary. (5)

Univation Systems
General Specifications
Management Science, Inc.
4321 W. College Avenue
Appleton, WI 54911
(414) 739-3616

1. UnivEl: System for standard time/methods instructions and data base generation.
2. MutiComp: Mass updating capability system for standards, methods, and data bases.
3. UniForm: System to generate standards for formerly "unmeasurable" jobs such as shipping, receiving, tool control, etc.
4. MiniComp: A system utilizing established methods and unique variables to rapidly and efficiently set standards. (6)

INFORMATION ABOUT ORDERING GOVERNMENT STANDARDS (DOD 5010.15. I-M) IS AVAILABLE FROM:

Publications Division
Distribution Branch
DASC-PD (Mr. Butler)
DLA: Cameron Station
Alexandria, VA 22414
(202) 274-6011

BASIC VOLUME, GENERAL GUIDANCE, JUNE 1977-Standardizes instructions, guidance, methods, terminology, for standard time data, work measurement, and the development of labor standards.



VOLUME II, CLERICAL AND SALES OCCUPATIONS, DECEMBER 1975-Provides standard time data for establishing labor and performance standards for clerical operations such as typing filing keypunching, etc.

VOLUME III, SERVICE OCCUPATIONS, JUNE 1975-Provides standard time data for establishing labor performance standards for service operations such as janitorial work, building services, and shoe repair.

VOLUME IV, FARMING, FISHERY, FORESTERY AND RELATED OCCUPATIONS, JUNE 1975-Provides standard time data for establishing labor performance standards for operations such as gardening and grounds keeping.

VOLUME V, PROCESSING OCCUPATIONS, JUNE 1975-Provides standard time data for establishing labor performance standards for processing operations such as electroplating; pickling; cleaning, and decreasing; heat-treating, etc.

VOLUME VI, MACHINE TRADES OCCUPATIONS , NOVEMBER 1974-Provides standard. time data for establishing labor performance standards for machine- trades operations (includes mechanical equipment repairing) such as boring, milling, grinding, lathe operations, etc. and aircraft, vehicle, and engine maintenance.

VOLUME VII, BENCH WORK OCCUPATIONS, FEBRUARY 1977-Provides standard time data for establishing labor performance standards for benchwork operations such as assembling, forming, molding, sewing, repairing relatively small objects and material such as metal products, electronic/electrical components, instruments, clothing.

VOLUME VIII, STRUCTURAL WORK OCCUPATIONS, JUNE 1975-Provides standard time data for establishing labor performance standards for structural operations aligned with the building trades and major end items or products such as aircraft, vehicles, etc.

VOLUME IX, MISCELLANEOUS OCCUPATIONS, JANUARY 1977- (Transportation, packaging, Materials Handling. . .)-Provides standard time data for establishing labor performance standards for operations such as transportation services, packaging, warehousing, materials handling, etc.

VOLUME X, UNIVERSAL, APRIL 1977-Provides standard time data for establishing labor performance standards, which are general purpose in nature and support two or more of the occupational categories. Includes elements such as get, place, walk, read, write. (7)

COMPUTER AIDED TIME STANDARDS (CATS)

For more information call (703) 841-3500 (in the Washington area) or (800) 336-3066.

Computer Aided Time Standards (CATS) uses the power of a computer to provide a rapid and simple means for finding and retrieving standard time data and/or standards , and for performing the necessary computations to build a time standard.



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THE FOLLOWING ARE ARTICLES FROM THE IIE MANAGER' S SEM IN MARCH OF 1980:

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- " Wocom"
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- "Univation systems"

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THE FOLLOWING ARE PUBLICATIONS OF IIE :

- Learning Curves: Theory and Application
- Fixed Interval Work Sampling
- Wage Incentive Plans
- Film Index of Work Measurement and Methods Engineering Subjects
- Rational Approaches to Raising Productivity
- Job Evaluation and Standard Time Incentive System
- Handbook of Industrial Engineering
- Indirect Labor Measurement and Control

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New York, 1963.

SEMINARS OFFERED PERIODICALLY ON WORK MEASUREMENT BY IIE



ANTICIPATED USES OF STANDARD DATA

Logically, the primary use of Standard Data will be to provide a powerful tool for ongoing industrial/manufacturing/production engineering programs. As indicated previously, the MARD funded shipbuilding industrial engineering program is using this data with a concentration on improved production methods and processes. However, several additional applications in this and other shipyard functional areas must be considered. The following is a summary of anticipated potential applications in three functional areas:

1. Industrial/Manufacturing/Production Engineering
 - a. Methods improvement
 - b. Tool, equipment, and machinery evaluation; selection and justification
 - c. Facility layout, flow, and workplace arrangement
 - d. Productivity improvement, i.e. delay identification and elimination
 - e. Manload balancing - critical path determination
 - f. Labor incentive systems
 - g. Make or buy analysis
 - h. Plant capacity determination
 - i. Long-range facilities planning
2. Production
 - a. Manpower distribution and assignment
 - b. Labor performance reporting and analysis
 - c. Productivity improvement, i.e., identification of delays, interferences, inefficiencies and possible solutions
3. Production Planning, Scheduling, and Control
 - a. Labor budgeting
 - b. Shop scheduling
 - c. Critical path development
 - d. Material requirements planning inputs
 - e. Group technology (process lane) planning inputs
 - f. Production cost estimating



USE OF ENGINEERED LABOR STANDARDS IN SHIPYARDS

Before the Methods and Labor Standards Program could be introduced to shipyards, a common work measurement system had to be selected for application across the participating shipyards. Four predetermined motion time systems (PMTS) were identified for application in developing **labor standard data for shipbuilding**. They were:

MSD	Master Standard Data
MTM-E	Method Time Measurement Level 3
MOST	Maynard Operation Sequence Technique
MTM-GPD	General Purpose Data

MOST was selected as the shipbuilding industry's formal predetermined motion time system so that standard data developed in one shipyard could be transferred to another with no problem in understanding the data. MOST was chosen because of the following features:

- Easy to learn and understand
- Can be applied from memory
- Has an accuracy of $\pm 5\%$ @ 95% confidence level
- High speed of application
- Methods sensitivity
- Reduced applicator deviation
- Universal application

The standard data developed with MOST is presented in the Work Management Manual. This manual is the official document for data application in each yard and also provides the vehicle for transferring the data from yard to yard.

The Work Management Manual (WMM) provides formalized documentation for:

- Organization conditions
- Standard practices
- Facilities
- Equipment and tools



Layout

- Material flow
- Method description
- Application procedure

Each of the manuals contains all the data required for a work measurement program for a particular area. The applicable data is usually in the format of an easy-to-use" chart or time formula. Such a chart follows. The chart provides all the data required to determine man-hours for each operation, station time, and elapsed time per panel. The chart is backed up with data derived for MOST sequenced models for manual operation and stopwatch readings of process times. Included in the time values is an allowance for personal, fatigue, and delay -- usually 15 percent.



WORK SAMPLING

Work sampling is based upon the laws of probability. A random sample from a large group tends to have the same pattern of distribution as the large group. If the sample is large enough, the characteristics of the sample will differ very little from the characteristics of the group. The percent of distribution of various elements, as they occur during random observations, tends to equal the percentage of the time spent on these various activities that would be found by continuous observation.

The accuracy of the work sampling study is determined by the number of observations taken. A greater number of observations provides a higher degree of accuracy. Thus, the accuracy of the results is a function of the number of observations taken over a sufficiently long study. The number of times a worker or machine is observed -- working, idle, or in any other state -- tends to equal the percentage of times in that state. This is true whether the occurrences are very short or extremely long, regular or irregular, many or few.

At the outset it is necessary to decide what level of confidence is desired in the final work sampling results. The most common confidence interval is 95%: the probability that 95% of the random observations will represent the facts, 5% will not.

In designing the work sampling study, consider the degree of accuracy. To obtain the desired accuracy, the following formula can be used (based upon a 95% confidence interval and assuming a normal distribution):

$$S_p = 2\sqrt{\frac{p(1-p)}{N}}$$

s = Desired relative accuracy

P = Percent occurrence of an activity of delay being measured; expressed as a decimal (for example, 40 % is 0. 4)

N = Total number of random observations (sample size)

In practice, few industrial engineers use this formula to calculate the number of observations required; it is easier to pick off the number from a nomograph or chart. See Principles of Work Sampling Chart 1 in this section for one such handy chart.

Work sampling, to be statistically acceptable, requires that each individual movement have an equal opportunity of being chosen; that is, the observations - must be random, unbiased, and independent. The use of a table of random numbers should be used to establish observation times.

In order to understand the actual technique of performing a work sampling study, turn to the Principles of Work Sampling.

Setting time standards for welding trailer frames may seem easy. But not when twenty different models are coming down the line, and time per frame ranges from two to eighteen man-hours. The authors found an unusual way to develop standard data.

DONALD W. BARNES, Serge A. Birn Company, Inc., Ft. Lauderdale, Florida
THOMAS NOWICKI, Dayton-Walther Corporation, Fayette, Ohio

Standards by the pound



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Mr. Nowicki holds a BBA degree from the University of Toledo, and has completed training in MTM and MSD. He is a member of the Society of Manufacturing Engineers.

To solve an unusual problem we developed what we consider to be an unusual yet effective approach to standard data time formula construction for the welding and assembly of heavy duty trailer frames. The formula was developed at the Fayette Division of Dayton-Walther Corporation. Although the principles used in the formula construction were of the standard variety, we feel that the techniques were used in a somewhat unusual way.

The manufacturing involves a product line of 20 models of trailers, all different in size, capacity, and/or length. Over 1,000 separate welds are required for assembly of the frame alone. The wide variety of trailers made it appear a very difficult task to set up standard data economically. A typical trailer assembly could vary in time from 2 to 18 man hours using a two-man team. The trailer welding area is shown in Figure 1.

Welding standard

Semi-automatic welding guns, using hard wire and CO_2 , are used in the welding operation, and the proper amp-volt setting for material to be welded had been established previously. Therefore, the rate of deposit for a given fillet should be constant. It was envisioned that the amount of welding wire used on each trailer could be precisely proportional to the time used to complete all welds on each trailer frame.

To determine the process time involved in trailer frame welding,

stopwatch studies were made of welding-wire spool revolutions during welding, Figure 2. These were determined to within 1/8th of a revolution of the wire spool. Recorded times were plotted against the various numbers of complete and partial revolutions of the spool. The curve resulted, as expected, in a straight line. Two quality control inspectors verified the number of welds made on the largest trailer used for the study and measured the length of each weld to the nearest 1/4 inch.

These were then compared to the resulting time values on the chart. The results were very gratifying. After counting and measuring 1,100 welds, and using the standard times based on the graph versus the amount of welding wire weight loss, the comparison resulted in 300 standard data minutes based on the weld count versus 303.9 minutes based on the amount of weight loss on a reel of welding wire. Each pound of wire used indicated 10.3 minutes of welding process time.

Supplementary tasks

Since the actual time spent using the welding gun could now be reasonably established, based on the actual amount of welding wire consumed, it was now necessary to determine what percentage of the overall trailer assembly operation actually consisted of welding process time. Over 1,000 work sampling observations were made over a four-day period. Control limits of plus or minus nine percent were

established to maintain statistical accuracy. All observations were well within these limits (minus 4.8 percent being the maximum deviation). The results of the study are shown in Table I.

Performance levels of the operators observed were noted during work sampling. Although there were some deviations (plus or minus five percent variation), an overall performance level of 100 percent was noted. To verify this, however, the work sampling data was tested with Master Standard Data (MSD) [Master Standard Data, *The Economic Approach to Work Measurement*, Crossan and Nance, McGraw-Hill Book Company, New York, New York, 1972].

Elements of some typical motion sequences were established and the resulting time values for those motion patterns were compared against stopwatch observations of an operator performing the same operation. In a large majority of the observations, the operators were within the acceptable plus or minus five percent limits of the MSD performance times. Therefore, no adjustment of standards for normal performance was required.

Application

A rate calculation sheet was then developed, based on the information that we had obtained to this point. To establish a time standard for any trailer welded in the assembly area, the analyst follows this procedure:

1. Before starting to weld a new trailer, two new welding wire reels, one for each operator, are installed at the workplace. When the entire trailer has been completely welded, each of the wire spools are weighed and the wire weight loss for the trailer assembly is calculated. The analyst then multiplies the wire weight loss in pounds by 10.3 minutes per pound — the normal time for the welding process.

To take an example and follow it through the succeeding steps, let us assume that the weight loss is 12.0 pounds. Then the normal time for welding is $12.0 \times 10.3 = 123.6$ minutes.

2. Next, the analyst divides the total normal minutes of welding

process time by 38.2, since work sampling indicated that 38.2 percent of all operations covered by the formula was welding. This establishes the base figure for the total operation. Applying this step to the example: $123.6 \div 38.2 = 3.24$.

3. Now, it is necessary to multiply the base factor, obtained in the previous step, by 7.7. Again, from the work sampling data, this includes grinding, torch cutting, and hoist use time. All of these are process-controlled operations. Example: $3.24 \times 7.7 = 24.9$ minutes.

4. By adding this last figure to the normal welding time (step 1), the analyst obtains the total normal time for the process-controlled operations. Example: $123.6 + 24.9 = 148.5$ minutes.

5. To provide the incentive allowance for the process-controlled operations, increase the step 4 time by 25 percent. Example: $148.5 \times 1.25 = 185.6$ minutes.

6. The analyst again takes the base factor (step 2) and multiplies it by 54.1 — the total percentage of manual operations derived from work sampling. Example: $3.24 \times 54.1 = 175.3$ minutes.

7. This last figure is increased for personal, fatigue, and unavoidable delay allowances and added to the total standard time for the process-controlled operations to determine the total standard minutes allowed for the assembly operation.

Example: $175.3 \text{ minutes} \times 1.15$ (assumed allowances) + 185.6 minutes (step .5) = 387.2 total standard minutes.

Conclusion

We realized that the approach taken to develop the formula was unconventional, but the operations involved in the welding and assembly of a wide variety of trailers had only one real constant that could be identified in the time available: the amount of welding wire used for each trailer. The resulting standards developed to date have all been reasonable and consistent. The formula covers a potential 11,900 manhours of labor annually, based on sales forecast data. Basically, only a little over one full week of industrial engineering time was utilized to develop the formula. TE



Figure 1. The trailer welding area in the Fayette Division plant of the Dayton-Walther Corporation.

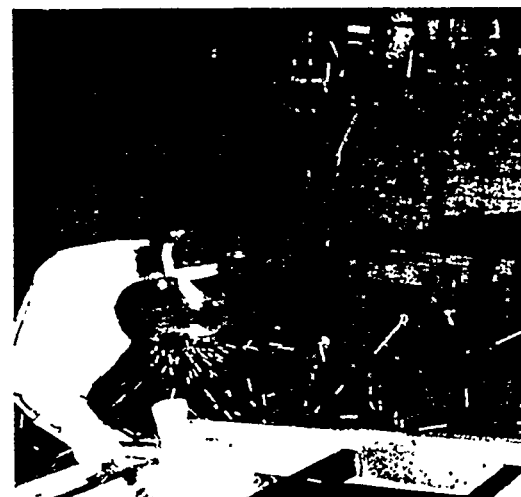


Figure 2. Time studies of welding were related to the usage of welding wire drawn from spools.

Category	Total number of observations	percent
Welding	381	38.2
Between welds	260	26.1
Clamping	71	7.2
Between clamping	48	4.9
Loading jig (per man)	94	9.5
Torch cutting	32	3.2
Grinding	16	1.6
Using hoist	29	2.9
Hammering	17	1.7
Loading new wire	3	0.3
Marking	17	1.7
Adjusting wire feeder	5	0.5
Gauging	22	2.2
Total, work categories	995	100.0
Absent	21	
Nonstandard	55	

Table I. Summary of work sampling study of welding and supplementary operations.



Work Sampling Exercise

- To understand how work sampling can be a useful tool in methods engineering, an exercise has been designed to use a set of slides representative of "a fit and tack operation. The operation involves a shipfitter on a panel line joining two or more plates together to make a panel assembly ready for seam welding.

The basic unit of measurement in work sampling is the observation, an action similar to a camera snaps hot. The observation is not of a worker--it' is of an activity that exists at the moment you make the observation.

Decide ahead of time what classifications will be used; ,don't be. uncertain. about them. Let the foreman know what procedures will be followed; be sure *not to* sneak around, or take data in a way that might cause suspicion.

Slides representing each working and not-working activity are included in the slide set. Activity categories follow:

Working Activities

Tally

Total

Receiving instructions (supervision)
Tacking
Removing slag
Material handling
Miscellare ous work activities

Not Working Activities

Personal
Not in area
Talk to other worker

Total Observations

When the slides have been completed, add the marks for each activity and also the total marks for the study. With this data, the time percentage for each activity can be calculated: $\text{No. Reading/Activity} - \text{No. Reading for Study} = \text{Actitivity Percent.}$

WORK SAMPLING'

Work Sampling is the use of the theory of probability to predict the makeup of something by observing a small portion of it. These prediction techniques are used by insurance companies and are fairly familiar to all of us.

Work Sampling is an inexpensive means of getting a fairly accurate measure of machine downtime, manpower utilization, crane wait, clean up, etc. in a plant or area.

This tool offers some unique advantages: time and cost wise, when applied properly.

The mechanics of Work Sampling lends itself to a logical five-step approach.

I Preliminary Estimate

II Plan

III Carry Out Plan

IV Check Data for Control.

V Check Final Results

I Preliminary Estimate

This is used to determine before hand the approximate number of observations that will be required. The preliminary estimate is simply a guess -- of the percent occurrence of the condition to be measured.

The estimate can be based on an intelligent guess based on past performance or in cases of doubt a series of fifty to one hundred observations can be used to calculate a rough estimate.

It might be well to point out here that one person or one machine observed is equivalent to one observation. If we were to observe a group containing three people or three machines, then each time we record the activity of the group we are making three observations.

Figure 1 is a sample, tally sheet of a preliminary study of a group of four machines. To estimate the percent running time divide $31 / 52 = .596$, this, then, is the preliminary estimate.

These observations can be used in -- the analysis of this operation and need not be discarded.

<u>Observation</u>	<u>Random Time*</u>	<u>Observations</u>	<u>Machine</u>	
			<u>Operating</u>	<u>idle</u>
1	8:20	4	4	0
2	8:55	4	2	2
3	10:30	4	3	1
4	11:05	4	0	4
5	11:25	4	3	1
6	12:55	4	4	0
7	1:00	4	0	4
8	1:05	4	2	2
9	1:55	4	2	2
10	2:45	4	4	0
11	2:50	4	3	1
12	3:10	4	4	0
13	3:25	4	0	4
Totals		52	31	21

Figure 1

II Plan

In order to plan the approach, there are two broad subjects to cover:

1. how many observations to make
2. how to make them

How many observations to make depends on two variables: the percent occurrence of the condition you want to measure and the deviation from this percent of occurrence you will be willing to accept. The percent of occurrence will be decided upon by one of the two methods discussed in Step I. The percent deviation from this percentage will depend upon the use you will make of the results. For general use we can use the same reasoning that we do in time study, that is a deviation from the "true" answer of ± 5 percent would be entirely satisfactory.

The formula most often used in the application of work sampling is:

$$N = \frac{4(1-P)}{d^2P}$$

where:

N = number of observations necessary
P = average percent of occurrence of condition being observed (expressed as a decimal - example 60 percent would be .6)

d = deviation from P that will be satisfactory (expressed as a percentage example ± 5 percent would be .05)

This formula is commonly referred to as the 95 percent confidence level. This means that 95 times out of 100 you can be sure that your answer will be within the precision you have prescribed in your choice of "d" in the formula. It is not necessary to use the formula to derive the necessary number of observations - the following alignment chart

(Chart 1) can be used to determine the answer directly. Note that in this chart the middle column is called precision interval - this is the acceptable deviation multiplied by the percent of occurrence ($d \times P$). This is the absolute error that is possible in the result.

CHART 1 - NUMBER OF OBSERVATIONS needed to get the precision you want is given by this chart. Here's how to use:

1. Estimate (or intelligently guess) the average percent of the work element you want to measure.
2. Decide what precision you want (for example, ± 5 percent).
3. Multiply your estimate of the average percent of the element by the selected precision to get the "precision interval."
4. Draw a straight line from the average percent, through the precision interval, to the number-of-observations line.

Example: To get ± 5 percent precision on work that's estimated to take 80 percent of workers time, you'll find that 400 observations are needed, according to this chart.

Once you have decided the required number of observations, it is necessary to decide how to make them before you have completed Step II. The first point we should consider is that work sampling is most accurate when your observations are made at random. This will assure that the result will be based strictly on chance. In deciding the frequency of the observations, two points have to be considered - how soon you need the answer and how long it takes to make an observation. The same two factors will determine how many ob -

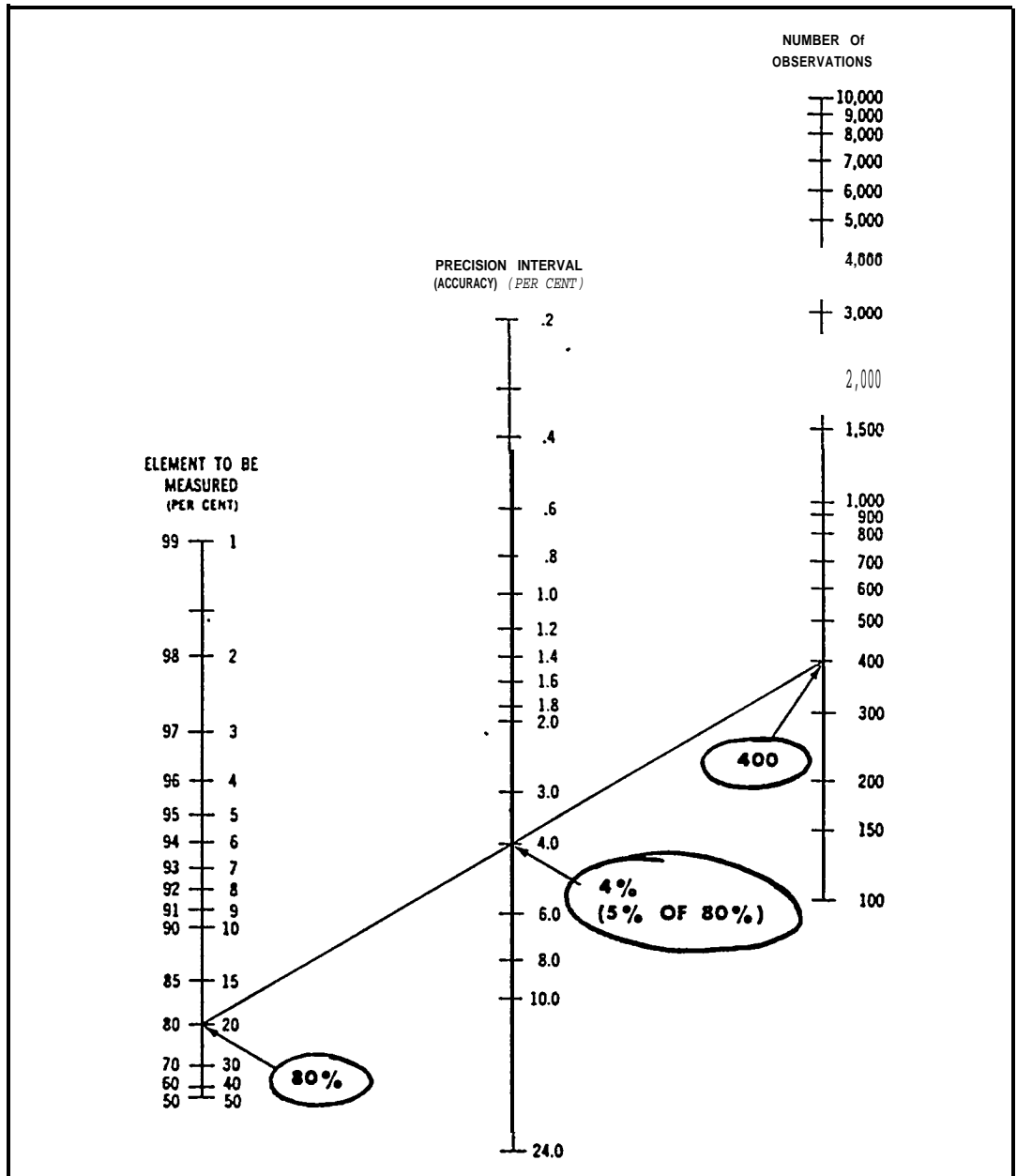


CHART 1
NUMBER OF OBSERVATIONS

servations you can make per day. For example, if the area you are sampling is so large that it takes 30 minutes to complete one observation trip, it is obvious that you cannot make more than 16 trips in a normal working day.

There are many ways that you can be assured of randomness by choosing your observation schedule completely by chance. A better and quicker way would be to use one of the following two

charts (Chart 2 and 3). Reference may also be made to tables of random numbers available in most statistics books. The JOURNAL OF AMERICAN STATISTICAL ASSOCIATION had such a table in their December, 1953 issue, page 931-934. In addition, you can introduce even more randomness by hinting more than one route to follow when making your observations in the area being studied.

Chart 2

TABLE OF RANDOM OBSERVATION TIMES FOR WORKSAMPLINGRead up, down, across, diagonally, or at random **in both tables to avoid a biased sample.**

Hours: (A. A.M., P= P.M.) Disregard hours not in shift concerned											
2P	SA	8P	7A	6P	12P	5A	7A	12A	11A	13A	8P
11A	12P	12A	3A	4P	5A	9A	7A	1P	10P	8A	3P
10P	7P	4P	3A	11P	3P	6P	9A	12A	2A	11A	4A
3P	3P	2A	10A	10P	1P	6A	1A	5P	5A	5P	8P
6A	6P	8A	1P	11P	9A	10P	2P	8A	5P	6A	5P
8A	3P	2A	5P	12P	6P	12A	9P	3A	4A	9P	10A
Minutes											
47	23	48	26	22	35	31	27	47	43	41	42
23	00	36	46	27	50	6	00	21	50	42	56
35	22	18	37	33	56	18	53	-	59	27	4
39	19	9	21	13	44	8	57	17	2	17	18
15	16	12	4	1	17	13	43	32	26	24	12
39	3	38	21	36	29	27	9	53	54	59	34
16	23	53	5	43	40	23	22	8	26	42	21
52	15	40	2	28	56	28	13	15	30	26	3
56	58	2	10	22	43	35	20	58	33	18	3
21	57	35	47	39	20	25	8	56	54	6	4

The following table of Random Sampling Times (Chart 3) was devised from a table of random numbers. This table lists twenty-five chronological random sampling times for each of twenty-one eight-hour work days. The figures which appear in the columns are easily translated into actual clock times. They represent the hours and minutes after the start of the work shift. For example, assume that the working period begins at 8:00 a.m. then the first sampling time of the first column, which is 0:05, would be interpreted as 8:05 a.m. Similarly, the last sampling time of the same column, 7:25, would represent 8:00 + 7:25 = 15.25 or 3:25 p.m.

By the proper use of this table, a list of random times of any desired length can be obtained. If twenty-five or less sampling times are planned for a day, one column will be sufficient. After the column selected has been translated into clock times, those times falling in scheduled rest and lunch periods are eliminated.

If the number of sampling times remaining is greater than planned, the numbers in parentheses to the left of certain times are used to reduce the list to the desired number. The secondary numbers indicate the order in which the times were originally selected from the random number table. In order to maintain the randomness of the list, numbers should be eliminated from the list in reverse order to their selection. Thus, if only twenty sampling trips were planned from Column 1, times designated as (25), (24), (23), (22), and (21); 3:15, 1:35, 6:20, 1:10, and 3:45 respectively, would be omitted.

Should more than twenty-five trips be desired in any one day, two or more columns may be combined and duplications eliminated. The same procedure as outlined above can then be applied to achieve the desired number of sampling trips. Different columns or combinations of columns should be used for planning the sampling trips for different days.

C r t

TABLE OF RANDOM SAMPLING TIMES

1	2	3	4	5	6	7	8	9	10	11	12	13	14
(19)0:05	0:20	0:10	0:15	(18)0:05	(23)0:10	0:15	(17)0:05	0:25	0:05	(25)0:05	(22)0:10	(25)0:10	0:10
0:20	(18)0:50	(16)0:35	0:25	0:25	0:25	(21)0:20	(18)0:20	0:30	0:15	(18)0:15	0:20	0:15	(17)0:15
0:55	(24)1:20	0:55	(16)1:20	0:45	(21)0:30	(16)0:35	(15)1:05	0:40	0:40	0:20	0:30	1:10	0:20
(22)1:10	(21)1:45	(24)1:00	1:40	1:05	0:40	(15)0:50	1:25	1:00	1:30	(19)1:45	1:50	1:40	(22)0:25
(20)1:20	1:55	1:10	1:55	(21)1:50	1:10	1:00	2:05	2:05	1:35	1:20	2:25	1:45	(24)0:50
(24)1:35	2:00	1:45	2:00	(20)2:10	1:20	1:25	2:25	2:30	2:25	(22)2:55	2:35	3:45	(18)1:25
2:30	2:30	(19)2:00	2:30	2:20	1:30	(23~1:40	2:40	2:40	2:45	(24)2:55	2:40	3:45	(16)4:45
3:05	2:40	2:05	(15)2:50	2:35	2:25	(22)1:50	3:05	3:05	6:05	(1s)3:05	4:15	6:00	(23)2:10
(16)3:10	3:10	(21)2:45	3:10	(19)2:35	2:35	1:55	3:15	3:15	6:25	3:15	4:25	6:05	(20)::::
(25)3:15	(23)3:30	2:50	(18)3:30	(17)2:50	2:40	2:45	(17)3:25	4:00	6:50	(17)3:25	(18)4:35	6:55	(17)7:45
3:25	(22)3:40	(22)3:00	3:45	(23)3:00	(24)2:55	(25)3:05	(15)3:30	4:15	6:25	(1s)3:05	(22)5:40	6:55	(17)7:45
(21)3:45	3:50	3:20	3:50	(16)3:10	(1s)3:05	3:50	(17)3:30	4:25	6:25	3:15	(25)6:45	6:55	(17)7:45
4:00	4:05	3:30	4:30	3:45	3:15	(19)4:00	(17)3:25	4:25	6:25	3:15	(25)6:45	6:55	(17)7:45
4:10	(16)4:15	(20)4:40	(20)4:40	(24)3:45	(17)3:25	4 : 2 5	(15)3:30	4:25	6:25	3:15	(25)6:45	6:55	(17)7:45
(18)4:35	(17)4:20	4:45	5:10	(15)4:30	(15)3:30	(18)4:45	(15)3:40	4:25	6:25	3:15	(25)6:45	6:55	(17)7:45
4:55	(19)4:25	4:55	5:20	5:00	3:40	(20)5:00	(16)3:50	4:25	6:25	3:15	(25)6:45	6:55	(17)7:45
5:00	4:30	5:00	(17)5:30	5:45	(16)3:50	5:10	4:00	4:25	6:25	3:15	(25)6:45	6:55	(17)7:45
(15)5:05	(15)4:35	(18)5:55	(25)5:45	(22)5:50	4:00	(24)5:15	4:00	4:25	6:25	3:15	(25)6:45	6:55	(17)7:45
(17)5:35	5:20	(25)6:00	(1s)5:50	5:55	4:15	6:20	4:15	4:25	6:25	3:15	(25)6:45	6:55	(17)7:45
5:55	5:35	6:05	(21)6:15	6:00	4:25	6:25	(18)4:35	4:25	6:25	3:15	(25)6:45	6:55	(17)7:45
(23)6:20	6:15	(23)6:35	6:20	6:35	(18)4:35	6:50	(22)5:40	4:25	6:25	3:15	(25)6:45	6:55	(17)7:45
6:45	(20)6:40	(15)6:40	(24)6:25	6:45	(22)5:40	6:50	(25)6:45	4:25	6:25	3:15	(25)6:45	6:55	(17)7:45
6:50	(25)6:45	7:10	6:50	(25)7:00	(25)6:45	6:50	(25)6:45	4:25	6:25	3:15	(25)6:45	6:55	(17)7:45
7:10	7:10	7:35	7:30	7:45	6:55	6:50	(25)6:45	4:25	6:25	3:15	(25)6:45	6:55	(17)7:45
7:25	7:35	(17)7:50	7:55	7:55	(20)7:35	(17)7:45	(20)7:35	4:25	6:25	3:15	(25)6:45	6:55	(17)7:45

(Cont'd on next page)

Chart 3 (Cont'd)

15	16	17	18	19	20	21
0:50	0:15	0:05	1:00	0:05	(20)0:25	0:25
1:10	(23)0:35	(17)0:40	(16)1:10	0:55	0:55	(17)0:35
1:20	(20)0:45	(25)0:50	1:35	(16)1:00	1:30	1:00
(15)1:25	0:55	(23)1:10	(21)1:50	(24)1:25	2:00	1:05
1:30	1:00	1:40	1:55	1:40	2:50	1:10
(20)2:00	(19)1:05	1:50	2:10	1:45	(21)3:10	(20)1:50
2:20	1:25	1:55	2:20	(18)1:55	3:15	(18)2:40
(24)2:40	2:20	(15)2:00	(23)3:00	2:05	(24)3:25	(24)2:55
2:45	(21)2:25	(24)2:40	3:05	(17)2:40	(19)3:35	3:10
2:50	2:35	(21)2:45	3:15	(25)2:50	(22)3:40	(25)3:15
3:10	(17)2:40	(15)3:15	3:50	(21)3:15	3:45	3:45
(25)3:35	(25)3:05	4:20	4:30	3:55	4:00	3:55
(16)4:00	(15)3:10	4:30	(20)4:50	4:00	(17)4:10	4:15
(21)4:25	3:15	4:50	4:55	4:05	5:10	4:25
5:00	3:30	(19)5:00	(24)5:35	4:15	(25)5:40	4:45
5:10	(16)3:40	5:05	(15)5:40	(23)4:20	5:45	(23)5:00
5:20	4:05	5:20	5:45	4:45	5:55	5:25
(17)5:25	(18)4:10	6:05	5:50	5:15	6:20	(19)5:30
(23)5:35	4:35	(18)6:10	(18)6:15	(22)5:50	(16)6:30	6:10
(19)5:55	5:10	6:40	(19)6:20	6:10	6:40	6:45
6:00	5:20	6:50	(17)6:35	(20)6:35	(18)7:00	(15)7:10
6:15	5:50	(20)6:55	(25)6:45	(19)6:45	7:05	(16)7:30
(22)6:55	(22)6:00	7:00	7:10	6:55	7:15	(22)7:40
(18)7:25	6:15	(22)7:35	(22)7:20	(15)7:00	(23)7:35	7:45
7:50	(24)7:50	7:55	7:55	7:50	(15)7:55	(21)7:50

The next thing that must be decided before the study is started is the form to be used in keeping a tally of the results. There is no standard form for this use. Its design will be based purely on your needs; that is, what information you want to gain from the sample. These can be as complicated or as simple as you desire. The form used in recording the machine utilization to arrive at a preliminary estimate of the percent of occurrence in Step I on page 2.11 is an example of a simple form. This could have been used to gather more information by adding a column to record the reason the machines were not running, such as, broken clutch, no material, operator personal time, set-up, etc.

III Carry Out Plan

At this point you are ready to go on with the sampling. One further point is worthy of discussion. Most texts devote considerable space to a discussion of

the mechanics of making a work sample. In the interest of brevity, only the most important points will be covered here.

1. All observations should be made from the same place (some people have actually put chalk marks on the floor by a machine to assure this).

2. All observations should be instantaneous - at the instant the observer reaches the point of observation he must record what is happening (he should not wait to see if the man is getting ready to start working).

The results of the observations should be calculated daily. Also, a running record should be kept of the total average percentage adding each day's result to all the previous totals. This will enable you to revise the necessary number of observations (by again using the alignment chart) if there is a significant difference in the actual percent

of occurrence and your preliminary estimate.

IV Check Data for Control

There are two schools of thought on what is necessary to assure that your results are statistically sound. The simplest is by merely plotting the cumulative average until the curve levels off. This is easiest to use and is probably accurate enough for some purposes.

However, this approach may be inadequate where a greater degree of accuracy is required. Before you can

say that your study is statistically sound you should look at the difference between each day's percent of occurrence and the total study average to ascertain that each day's results are within the daily allowable variation. This is a control " " tool and should not be confused with the original acceptable percent deviation because daily deviations may exceed the original estimate and still be statistically-correct. There is a formula for this check but it has also been put into the alignment chart form and follows (Chart 4). Please note that the right-hand line is expressed in observations per day. The example under the chart points out that information falling out -

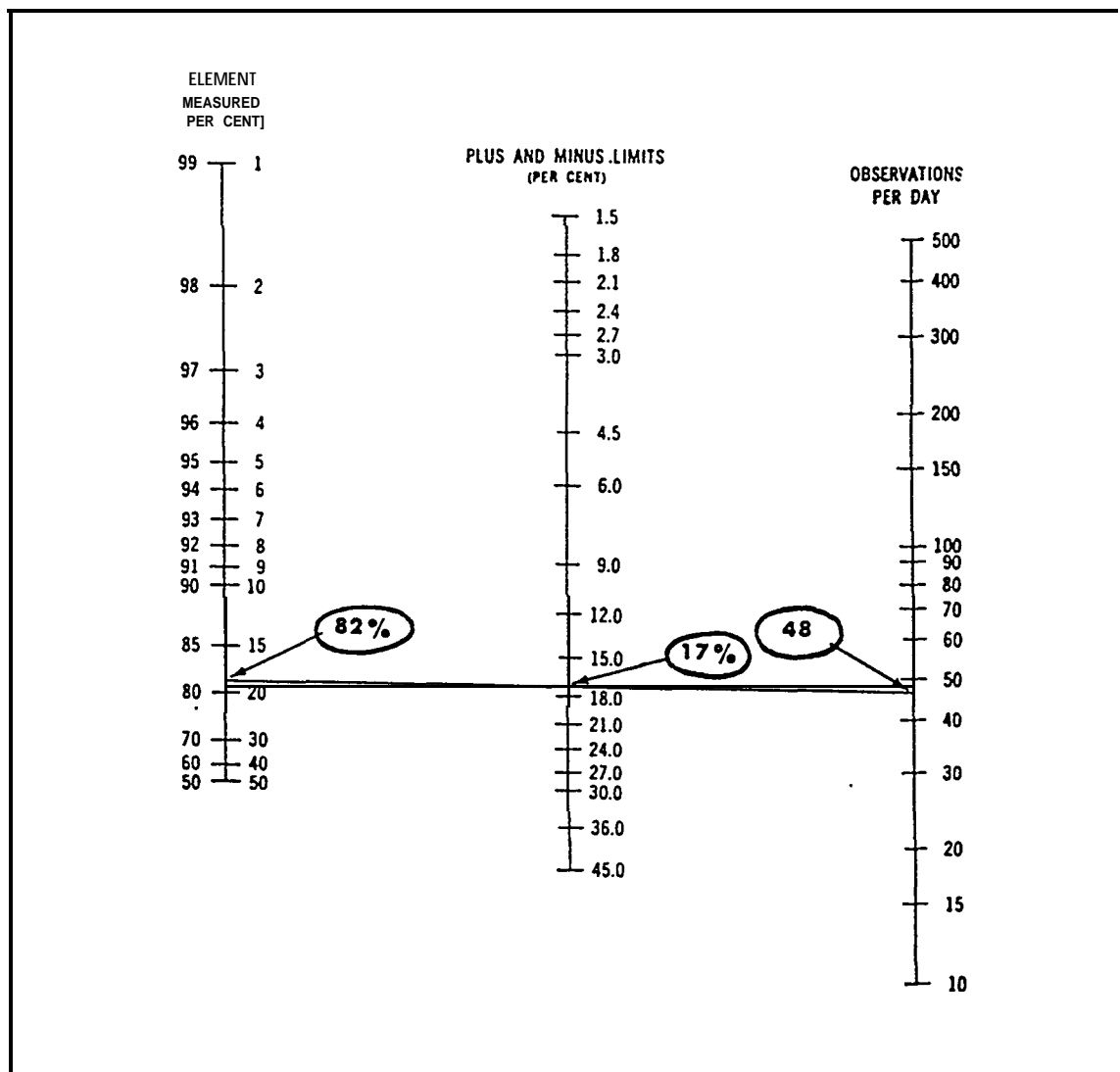


Chart 4 - **CONTROL LIMITS** for your Work Sampling study results are found in this chart.

side the limits should be discarded from the study because the final average percent of occurrence must come from observation of similar work conditions to be meaningful.

To use Chart 4:

1. Mark on left-hand line the observed percentage of the element measured.
2. On the right-hand line mark the total number of observations made each day of the study.
3. Connect the two points by a straight line.
4. Read the allowable variation (control limits) on the center line.

Example: If the average handling activity during a ten-day study is 82 percent, and the number of daily observations 48, then each day's percent activity should be between 65 percent and 99 percent (82 ± 17 percent) to be statistically stable. Find the cause for any day that is outside limits. Data connected with that cause should be thrown out in order to achieve the statistical reliability you're looking for.

After completing Step IV the data will be in statistical control and then, and only then, you can check the final deviation by use of the original alignment chart used in Step II on page 3. By lining up the final percent of occurrence and the actual number of observations, you can read the precision interval *on* the middle scale. Divide this by the percent of occurrence and this will tell you the actual deviation (d). In other words, you can be 95 percent certain that your answer is the percent of occurrence plus or minus this resalting deviation. If this doesn't offer the degree of accuracy required, more observations will be necessary.

RANDOM SAMPLING NUMBERS

90 78 82 54 47	20 83 80 10 41	35 22 23 03 98	75 74 41 35 05	78 73 95 47 83
78 58 68 87 41	11 08 81 29 89	71 23 10 01 79	25 06 00 45 80	64 70 95 34 29
51 42 21 03 88	20 05 35 93 00	68 12 09 55 09	36 54 95 22 82	48 30 09 56 87
93 15 07 60 86	67 37 94 24 35	82 44 19 92 96	21 84 29 04 29	83 32 05 10 48
27 12 31 66 62	09 54 17 31 23	27 30 37 36 79	75 50 39 57 12	67 23 22 09 33
79 44 83 55 47	96 50 93 56 82	58 16 35 18 87	64 08 22 47 93	86 43 43 30 17
89 73 43 91 03	57 91 35 40 64	13 61 94 37 16	09 93 96 25 87	30 23 42 54 31
29 30 90 00 58	15 99 93 33 67	80 08 59 21 66	13 54 56 85 25	05 32 03 52 52
97 33 17 26 25	04 73 18 10 05	34 40 32 65 07	28 68 29 31 97	89 57 95 55 16
07 15 44 92 47	28 50 93 03 53	37 70 19 66 59	95 39 87 90 46	98 64 46 24 71
82 50 35 50 80	23 67 81 25 02	83 08 12 70 00	25 31 33 80 06	19 86 14 59 27
59 21 86 16 30	27 85 16 26 34	50 15 87 22 69	71 36 95 90 76	90 99 79 63 21
04 19 60 33 05	29 02 33 74 56	38 84 21 07 35	93 54 70 12 47	14 62 75 45 02
96 91 44 09 94	06 89 50 88 83	82 50 11 82 51	30 68 91 06 28	86 65 17 45 20
31 71 03 53 38	94 02 52 72 15	44 49 53 42 43	00 36 97 67 64	12 27 46 00 18
03 70 22 67 59	98 10 64 68 08	79 06 89 48 41	85 72 10 87 24	96 04 20 68 00
08 45 79 46 89	74 73 67 60 15	70 37 61 44 07	67 89 81 54 26	57 17 63 27 74
37 80 05 75 64	48 51 68 68 27	71 75 45 32 27	76 35 26 58 88	67 74 48 90 94
90 63 56 69 37	19 74 48 63 31	52 36 84 40 66	72 66 03 41 87	65 29 12 36 64
22 69 38 02 22	89 71 43 01 87	41 79 42 99 29	41 08 47 32 19	45 29 59 69 90
05 79 69 67 64	36 14 82 65 26	40 51 63 42 48	85 48 34 12 04	33 26 52 26 52
48 91 53 03 82	64 24 06 31 03	97 44 82 24 89	88 48 66 54 10	41 27 09 11 61
94 64 97 27 25	62 23 94 40 54	56 32 97 78 90	58 86 41 75 19	42 90 85 36 68
15 85 82 52 08	52 96 26 92 88	93 11 03 23 52	78 23 57 85 43	53 90 42 22 22
09 81 37 66 56	99 08 59 19 48	29 69 21 64 95	12 08 15 24 45	59 25 22 76 96
43 83 99 02 76	12 16 45 52 66	35 70 93 09 52	75 40 34 35 62	65 42 27 20 59
31 98 09 80 62	75 26 64 57 26	46 41 47 90 97	99 46 10 51 42	73 28 98 89 91
81 35 42 62 84	37 02 59 78 16	17 96 05 71 39	88 05 34 05 92	22 43 89 66 89
97 95 56 39 75	65 47 61 86 33	14 88 55 33 69	70 87 79 94 46	17 61 72 27 01
37 63 35 93 23	17 30 14 51 51	17 28 21 74 67	12 11 57 19 27	38 70 73 82 92
39 22 96 00 48	52 49 62 09 40	08 30 27 54 70	96 06 52 12 80	36 12 38 68 05
61 29 84 34 51	60 19 77 82 16	64 45 02 27 04	65 55 90 95 04	20 39 29 96 28
38 84 18 10 29	19 09 66 06 78	37 09 60 50 21	52 72 01 52 70	29 65 05 37 16
64 29 48 04 08	55 72 25 25 77	54 26 27 24 39	66 67 06 40 00	99 35 70 69 58
64 02 32 99 63	62 42 89 32 20	81 14 08 40 45	22 15 37 49 38	96 51 19 08 27
13 83 39 51 30	31 49 94 83 66	02 50 95 18 98	58 84 90 58 81	00 40 91 12 46
83 30 90 09 35	41 12 87 93 66	85 96 20 65 34	23 13 05 41 01	91 48 95 59 45
46 63 53 97 63	18 86 37 56 20	35 62 66 11 37	30 91 89 97 51	64 78 06 95 65
54 43 40 02 41	55 70 52 96 87	02 82 61 21 88	60 65 98 42 09	03 61 20 83 01
27 18 65 62 01	97 45 79 51 37	74 47 20 11 48	97 93 73 86 50	46 61 95 01 24

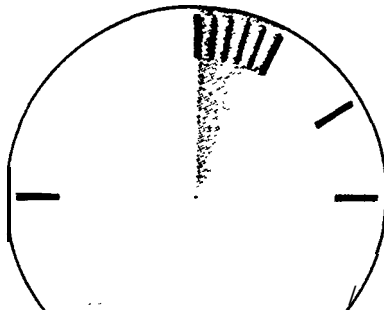


GROUP TIMING TECHNIQUE WORKSHOP

The Group Timing Technique is a valuable industrial engineering tool that can be used in the shipyard. GTT combines the advantages of time study and work sampling to generate statistically accurate labor standards.

The best method to train people in the use of GTT is to conduct an actual GTT study in the yard. Another approach to GTT training involves classroom use of a super 8mm movie or videotapes of an operation and using simulated time sequences.

The following article, "Timing Those Group Operations, " reprinted from Industrial Engineering, covers the subject of GTT thoroughly and should be read before conducting a GTT study.



Timing those-group operations

Get a handle on standards for crew-sized operations using this simplified work measurement technique. The results can be as statistically accurate as any standard; the trick is judging the group rate and selecting proper observation time intervals. Number of products produced is the key.

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Group Timing Technique (GTT) is a tool that can be used to develop accurate labor time standards for variable-size crew jobs where members of the crew are performing the same task at the same time. The technique can best be described as work sampling with observations taken at repeated constant time intervals. It produces results quickly because many work elements are seen at each observation.

Similar to work sampling, the idea behind the technique is that whatever is occurring at the time of observation has been occurring for the entire interval since the previous observation. Another similarity is that a group of operators, in the same area, may be observed simultaneously, and their individual activities recorded. One difference is that the constant sampling interval and production count provide a means of relating element times to production output.

Random work sampling provides a measure of the occurrence percentage of the elements, and usually does not relate directly to units produced. GTT provides not only a percentage breakdown, but data that can be translated into element times required for each unit of production.

Results can be obtained in about one-half the time that would be required by the stopwatch method. Fewer samples are usually required than needed by random sampling techniques. This is because each GTT sample provides the maximum amount of data.

“Chinese fire drill,” “organized chaos,” or out of control jobs can be successfully analyzed and evaluated by this system. GTT works in situations where regular time study technique is next to impossible because it is independent of the particular individuals in the group being studied.

It is ideal for studying groups of people producing measurable output in a reasonably limited work area. Ideally, all work activity should be within eye range of the observer. Jobs such as shipping crews, unit assembly crews, maintenance crews working on specific tasks, groups of production operators doing the same task, and clerical-type office work are good examples. Best results are obtained when evaluating tasks involving 3 to 10 people.

Making a GTT study

1. Select the operation, group of operators, and time periods to be studied.

2. Study the operation to establish:

Elements (including idle and/or missing). The elements should cover all aspects of the job. Performing all the elements should produce a completed product or product stage.

Element duration and sampling interval length. The elements selected should have clearly defined starting and ending points, and be long enough that a change during the instant of observation is Unlikely. The sampling interval, or interval between observations, should be long enough to permit recording the observation data.

Operation location scope. The activity area should be small enough, and the observation position located such that all activities can be observed and identified in a quick glance.

Crewing variation. The maximum and minimum crew size should be established in advance of the actual recorded observations. This information will allow immediate entry of the idle and "missing" observations

Measurable units of output. The units of production must be clearly defined. The units should be either small enough that a definite number can be counted as produced during the total observation period; or the study should be planned so that a continuous sequence of observations covers the production of a single work unit from beginning to end.

3. Decide on, design and reproduce the recording format. (A typical recording sheet is shown as Figure 1.) The format should provide for recording the following information:

The overall description of the job

Date of study

Start and finish time of observation period

Sampling interval length

Equipment identification

Operator identification

The number of units produced during the sampling period

The job elements

The pace rating

Other information, such as the maximum number of operators on the job, etc.

The format should be designed for ease of calculation.

4. Make the Study. Fill in the base data: date, job, and start time. Begin observations. The observer should position himself where he can see the entire job or all the job stations at a single glance. Use tally marks to indicate occurrence of elements.

Continue observations until all periods are covered and an adequate number of samples has been taken to provide the desired accuracy. A typical completed data sheet is shown as Figure 2.

5. Recapping the observation data.

Total the tallies for each piece made.

Total the tallies for each individual element.

Multiply each individual element tally total by the sample interval size. The result is the total time spent on each element.

Adjust this time by the rating factor, if any. The result is leveled time per element.

Divide the leveled time for each element by the total number of pieces made. The result is leveled element time per pieces. Figures 3 and 4 show the calculations.

Different from time study

There are several key differences between GTT and the usual time study methods:

1 More than one operator is studied at the same time

. Observations are taken at constant time intervals

. The study is not dependent on any specific duration of any session, but can be interrupted at any time without loss of effectiveness

. Continuous eight-hour study is not needed

. The data recap paperwork takes less time.

The basic conditions for using GTT are that all the operators observed and included in the study must be related to producing the product measured, and that they all can be observed at the same time. (This requirement can be "stretched" a little bit by allowing the observer to survey a 360-degree field from one vantage point.)

The elements must be simple enough to permit rapid classification. But they should be long

enough so that a change during a given observation is unlikely. The idea, as in random work sampling, is to take a quick "scan" and record the first observation. Since the time interval between observations is usually short, GTT is a demanding system to apply. As with all techniques, a sloppy or inept observer will not produce valid data.

The observations can be taken at any constant time interval. Obviously, the shorter the interval between observations, the more observations you will get for a given

Date: One Sample per ___ min. Time: Finish
Start
Rack Type 8, 27, 40 column
No. Packages/column 6, 7, 8
Max. no. of operators working on task
Package Type: Crimped, uncrimped
Work Rating

Loading Packages

Assembling parts to rack

Obtaining parts for rack

Idle - Wait
Interference

GTT Loading & Unloading Kier Racks

Date: 4/30/76 One Sample per .5 min. Time: Finish 0940
Start 0756
40

Rack Type 8, (27) 40 column } Total packages = 189
No. Packages/column 6, (7) 8

Max. no. of operators working on task 4

Package Type: Crimped, (uncrimped)

Loading Packages

[Handwritten musical notation]

Assembling parts to rack

[Handwritten practice strokes for the letter 't' in various styles and orientations.]

Obtaining parts for rack

1111 1111 1111 1111 1111 1111 1111 1111 1111 1111
 1111 1111 1111 1111 1111 1111 1111 1111 1111 1111

Idle - Wait
Interference

1111 1111 1111 1111 1111
 1111 1111 1111 1111 1111
 1111 1

Missing

Handwritten notes in cursive script, possibly a list or a set of instructions, written on lined paper. The text is difficult to decipher due to the cursive style and fading.

Obtain Rock
111

Figure 1. Recording sheet for typical operation.

Figure 2. Observations have been completeG.

period of time, and you will also see needed, it is important that observation duration elements. Of course, observations are made during all time the shorter interval gives less time that the work could be in progress. This insures that all activities are recognized. It is important to develop as fair a sample of the work activity as possible. The data recap paperwork takes less time than time study, mainly because it is a matter of counting

The sequence of operations can be interrupted with no ill effects at any time, provided that the number of products completed during the observation period is recorded. The idea is to be able to relate element observations with product produced and, or task accomplished.

Although a continuous eight-hour observation session is not

needed, it is important that observations are made during all time periods that the work could be in progress. This insures that all activities are recognized. It is important to develop as fair a sample of the work activity as possible.

The data recap paperwork takes less time than time study, mainly because it is a matter of counting tallies against each element, rather than averaging groups of decimal numbers. Another factor is that far fewer readings are required to achieve the desired accuracy.

Yet, similar to time study

GTT is not a magic wand-waving technique. It requires the same

basic preparation needed for routine time study procedure. It is still necessary to:

- Identify all elements
- Develop a measure of the work accomplished (pieces made, handled, etc.)
- 1 Use performance rating to finally adjust the values against a constant scale
- 1 Determine the number of observations required to assure statistically valid data.

The elements of direct and indirect work, instructions, idleness, absent, etc., must be identified before the recorded observation begin. Just as in routine time study preparation, this is best accomplished by a recorded observation of

GTT Loading & Unloading Kier Racks

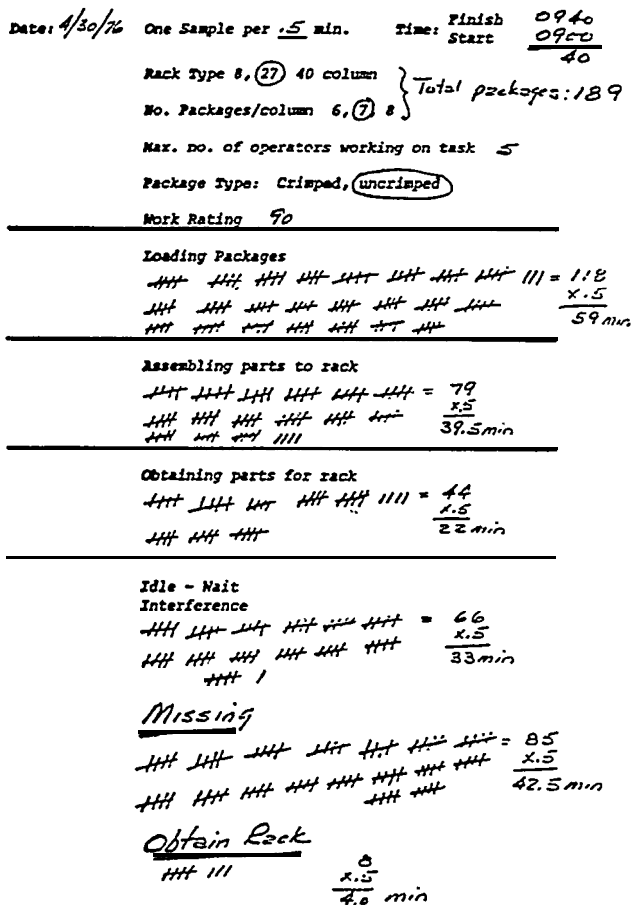


Figure 3. Total time for each element determined.

GTT Loading & Unloading Kier Racks

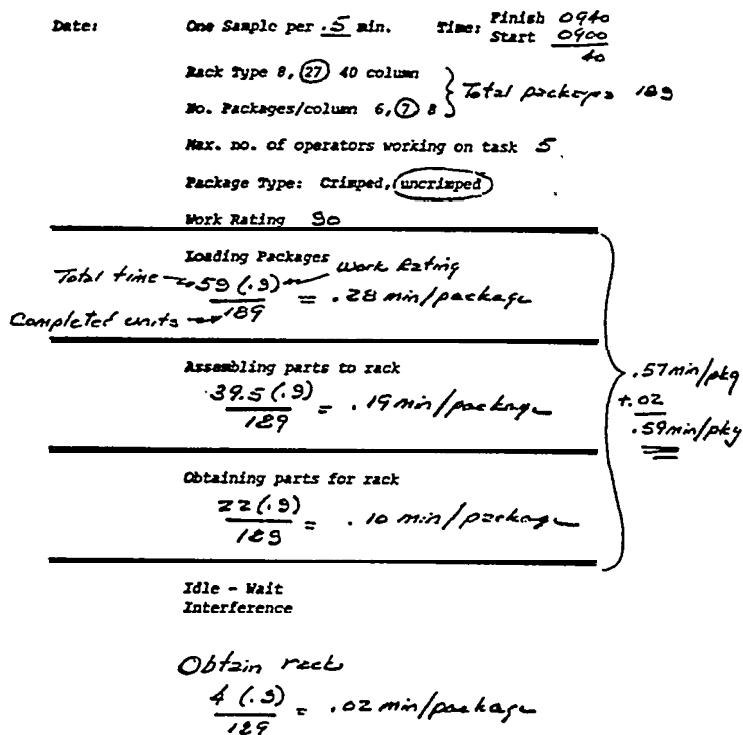


Figure 4. Final step, leveled time per piece.

the actual job. The scope of each element will be determined by the level of detail desired. In most cases, the elements used for GTT will be the same as those which would be used for routine time study.

The need to develop and apply a measure of the work done cannot be overemphasized in the application of GTT. Unlike routine time study which usually follows an individual operator through the sequential steps on a continuous time basis, with each increment of time assigned to a specific element, GTT produces a recording of the frequency of occurrence of each element. These frequencies are then related to the interval of time between observations. The result is

compared to the units produced during the observation period to develop element times. These element times are assembled, just like direct read stopwatch times, to build the total work time standard. Because of this interrelationship, GTT observations are worthless if the corresponding units produced are not recorded.

As in routine time study, operator rating, or overall work pace rating, must be used to standardize the data. If this is not done, data derived from observations on an above average crew will produce unrealistic, "tight" standards. Likewise, data from poor crews will produce "loose" standards. The main difference in the application of rating

technique to GTT is that the overall pace for the crew must be applied to all the observations for each element, as compared to individual ratings on each time recording in routine time study. An observer who has developed proficiency in rating individuals will experience little difficulty in rating group performance.

The Industrial Engineering Handbook, 3rd Edition, (McGraw-Hill, 1971) has formulae which can establish the number of GTT readings required to assure acceptable statistical accuracy. As with any other industrial engineering study, statistical verification in support of the conclusions is essential.



WHERE SHALL WE MEASURE?

At this point we should review our major premises of the workshop before going on to the measuring unit.

Early on we talked about the "questioning attitude. " We do not question because we are congenial skeptics; we question because it's a good mental attitude to have when linking to solve problems.

Many small problems can be discovered by this questioning attitude, and the answers are often discovered as we become aware of the problems.

Large problems are different. In early phases, they may range from the unsuspected to the obvious. But a large problem (an opportunity to make or save money) is usually difficult to pinpoint in the early phase.

There are proven problem-solving techniques to guide us through the various steps. See Figure 1.

Note that during the definition phase and report phase of problem solving, data must be measured and presented. Flow charting and work sampling techniques (previously discussed) are probably the most powerful tools available to the methods engineers.

Engineering implies measurement and definitive information. Communicating the situation to others requires understanding the problem and a clear and understandable presentation. This usually requires the taking and presentation of data. Some effective ways include:

1. Flow charts
2. Charts, diagrams, and curves
3. Scatter diagrams
4. Histograms

Before we start on data presentation, a few observations:

- 1 Remember that this is not a mathematics course. Data presentation is just a way of graphic communication. Data taking, simple arithmetic operations such as grouping or calculations, and presentation definitely help understanding of the problem by all.

Most data follow Pareto's Law, named after an Italian mathematician. He observed:

1. Things often break down into a trivial many and a critical few.
2. In most business activities, a small fraction (approximately 20 percent) of the total item count produces the major portion (around 80) of the work, cost, profit, or other measures of importance.



Flow Charting

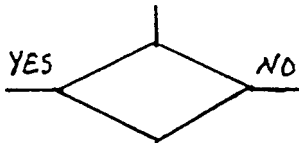
You have received examples of some of the industrial engineering type flow charts. Don't get too fancy. In an initial phase, use some of the symbols of logic or "computer type" flow charts. Some of these are:



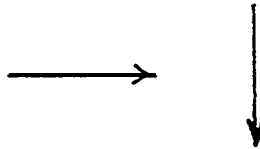
Input or Output Device



Processing



Decision



Direction of flow
Usually left to right, top to bottom

Charts, Diagrams, and Curves

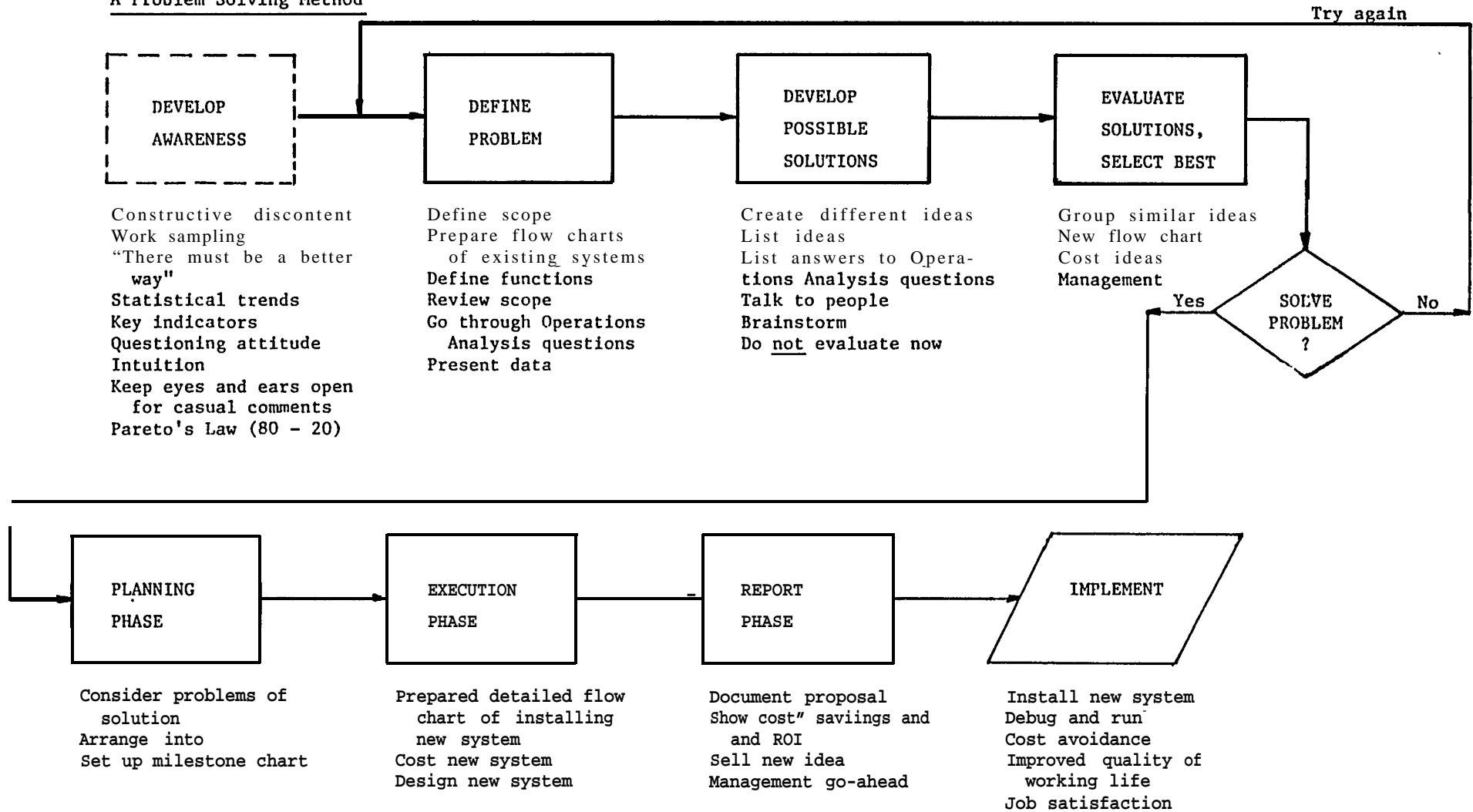
Charts present data graphically. Usually, people can comprehend better with an image than with the data numerals; and, a combination of the two is stronger than either by itself.

Where we measure is usually taken from the problem itself. Very often the calendar of working days is taken as the independent variable or some other known or controlled variable. The quantity that varies as a function of time or other controlled variable can be plotted in comparison. Dollars spent, man-hours, percentages, dimensions, and out going quality are often dependen t variables.

One of the first ways to present data is with a chart. With only five or ten readings this method is sufficient. Chronology is plotted in one vertical column from top to bottom and the other variables are entered opposite the values in parallel vertical columns.

Figure 1

A Problem Solving Method





Here are some ways to present data showing a comparison of order size (independent variable) and production cost (in this case operation hours).

The raw data as obtained from accounting: order size - operator hours.

30 - 120	53 - 176
48 - 161	25 - 130
35 - 140	33 - 130
45 - 165	39 - 150
40 - 160	45 - 150

The raw data shows us information but it's hard to make much sense of it.

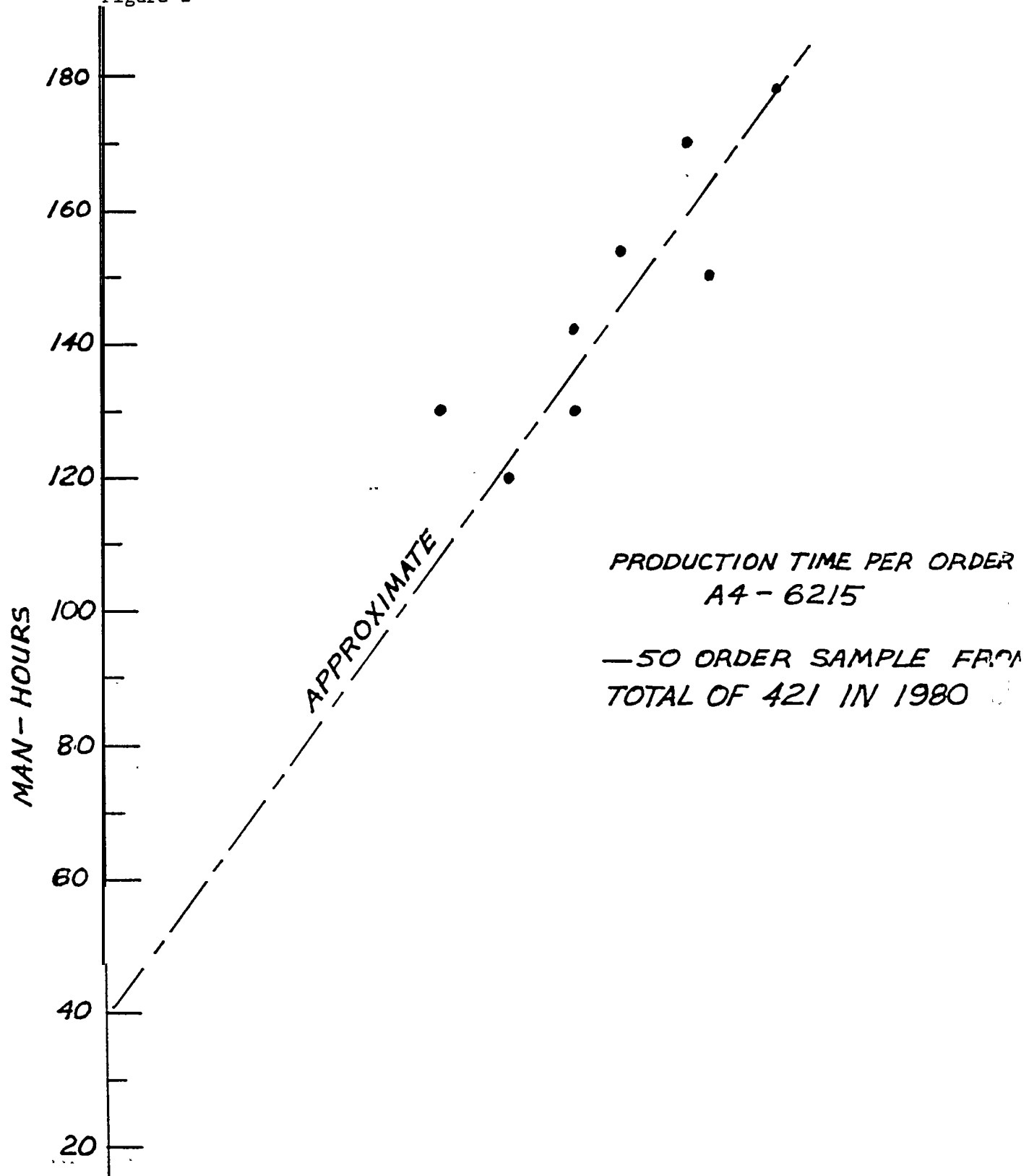
The first step is to arrange the data into an ordered array: tabulation by "putting the independent variable in numerical order. This would give

ORDER QUANTITY	1	OPERATOR HOURS
35		130
30		120
33		130
35		140
39		150
40		160
45		165
45		150
48		161
53		176

Many other charts and diagrams are available to present data. Just remember the concept of independent or controlled variables and the associated dependent data (bivariate data).

Of special interest to the methods engineer is the scatter diagram (see Figure 2). It is a chart showing the independent variable plotted on the Y-axis. The scatter diagram shows more information than the charts previously shown. First, it shows whether a simple relationship exists. This is much easier to determine than looking at charts. Second, it shows how linear or how close the relationship is to a straight line or "fair" curve.

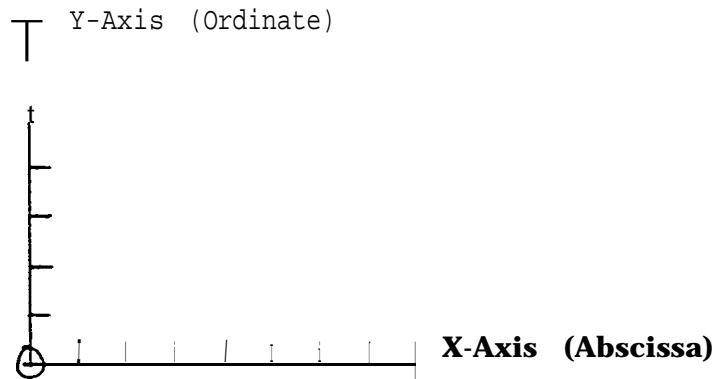
Taking the diagram (Figure 2) and using some practical "regression analysis"





Conventions in X-Y plotting are: the X-axis (horizontal) is the independent variable, or abscissa. If you can adjust it, or select it, the variable is independent. The dependent variable, or ordinate, is plotted on the Y-axis or vertical axis. The dependent variable is a function of the independent variable.

Families of curves result when a third, adjustable variable is held constant while the other two are varied and plotted.



Within these definitions you would normally plot time, hours, days, the calendar, orders, etc. on the X-axis. The Y-axis often includes hours worked per day, standard hours produced, percentage of total, output, dollars spent, variable time, utilization, yield, rejects, etc.

Histogram

A lot of single-value numbers (univariate data), perhaps 30 or more, present a different problem. Several established ways are ordered array, averaged, or plotted as a frequency histogram.

The histogram is a graphic device for univariate data and is quite useful because it conveys the impression of the shape and pattern of the distribution at a glance. It is handy in showing information where you are interested in the median or central tendency, or a production distribution with high and low rejection points.

Typically, histograms are plotted using samples of 30 to 100 or more. Usually the quantity is plotted along the vertical or Y-axis, and cells or classes are set up along the horizontal or X-axis. The number of cells is important and should be selected with an idea of clearly presenting the information wanted. If you have upper and lower control values you may want to put these at an edge of a cell so that the histogram clearly shows whether the parts are acceptable or rejected.

Here is a chart showing typical numbers of cells for various numbers of observations. Adjust as indicated.



No. Readings	No. of Cells
30	6
50	7
100	8
200	9
400	10
1000	11

For setting up cells, the "break points, " or intervals, may well follow your own convenience. Groupings of 5 or 10 may be handy, or use other convenient intervals. On the other hand if lots of values fall on whole numbers, you may want to set your cells 4.6 to 5.5, 5.6 to 6.5 6.6 to 7.5 etc., so that the value of 5.0, 6.0, 7.0 falls clearly within the cell and not on the transition value.

When a histogram or any chart or diagram represents a sample of a larger population, remember the quantity must follow the statistical sample number for the data to be valid.

See Figure 3 for an example of histogram plotting.

Another way to show univariate data is to plot relative rather than absolute frequencies. The example histogram uses absolute frequencies of the quantity, the actual count. These could have been easily converted to relative frequencies by expressing them as a percent of the total observation. This information would show more than an ordered array chart and it can be plotted using the percentages instead of the absolute frequencies.

Relative frequency tables and graphs are particularly useful when two frequency distributions involving different numbers of observations are to be compared, such as a before and after comparison.

There are several other ways to present these kinds of data: cumulative frequency distribution, cumulative percentage frequencies, etc.

Histogram Example

Production order man-hours per job, 50 samples.

55	40	16	18	31
93	84	15	25	80
82	88	37	32	89
53	72	18	40	12
68	32	29	42	32
50	36	21	20	17
81	10	30	25	14
79	9	35	26	21
22	40	35	19	43
21	32	25	27	25



Not much can be deduced from these raw figures although we could easily calculate the arithmetic mean:

$$\bar{x} = \frac{\text{total}}{N} = \frac{2040}{50} = 40.8$$

Setting up a histogram with 7 cells would have inconvenient values. Try 10.

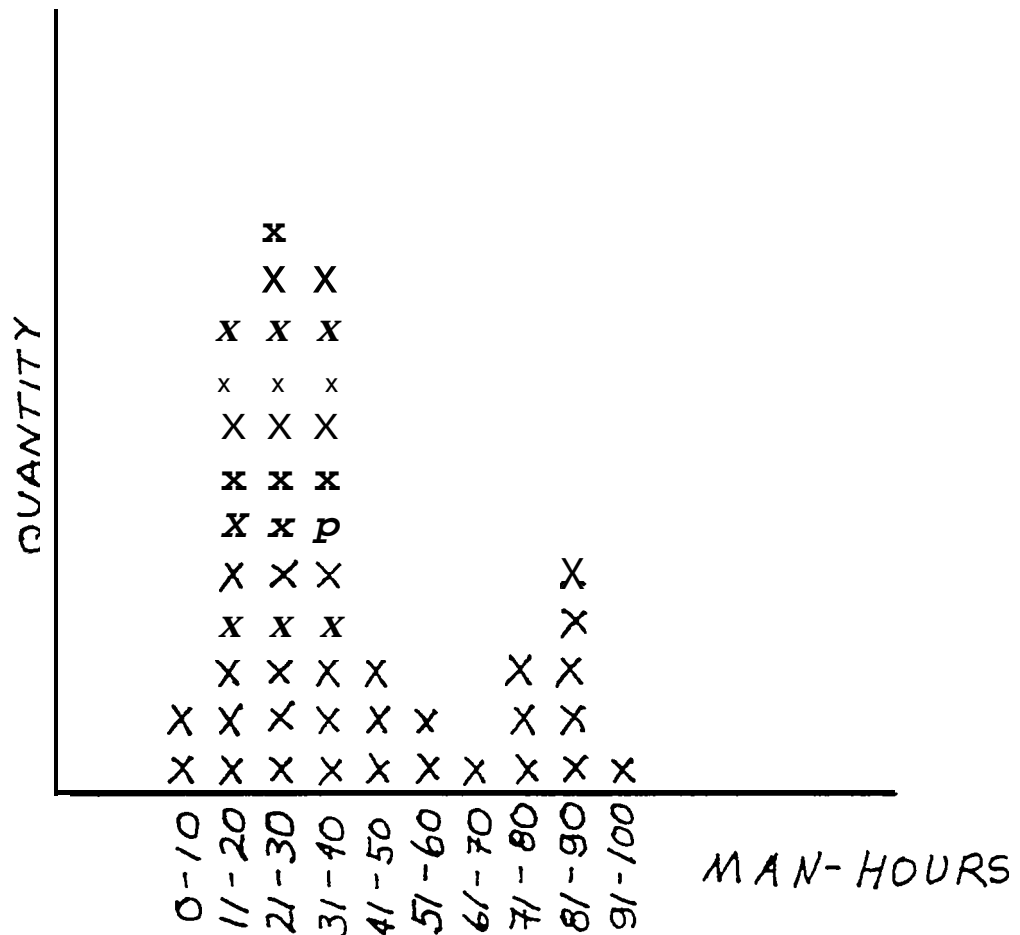


Figure 3

Other Ways

We normally think of data presentation as an exercise involving graphs, charts, and figures symbolically representing a practical solution,



Other ways can involve photographs of the actual situation, photographs of models, sketches of the situation before and after, and video and film motion pictures.

Take data and present them carefully. Good data help us understand the problem and sometimes has an uncanny way of leading us to a solution.



APPENDIX 1: MATHEMATICAL TERMS

The quality of data has an important influence on outcome. Figures, charts, and diagrams give the illusion of being correct and valid. Technology-minded people must concern themselves with making the illusion a reality.

To review:

Data	One or more measurements or observations. Data is plural; a single measured or observed value is a datum.
Accuracy	This expression is a measure of the difference between the data and the <u>true</u> value of whatever the data represents. Usually expressed as a percent.
Validity	A number or numbers are said to be valid if they <u>measure what they claim to measure</u> . Valid data is that appropriate for the use intended.
Precision	A measure of the <u>repeatability</u> of the data. It may be inaccurate, but similar observations produced similar results. Don't use <u>precision</u> when you mean <u>accuracy</u> .
Observation	A measure of the data in one elementary unit included in a sample.
Sample	A group of observations drawn from a universe or population. Done properly, a sample gives knowledge of the universe " from which it came. " The sample size must be large enough, given the required accuracy and confidence levels, and be taken in a random way.
Universe	A collection of things as they really are. Sometimes called population or parent group.
Numeral	A symbol used to stand for a number. The characters 2,3,4 are numerals.
Number	An abstract idea or concept to understand arithmetic or " how many. " " Positive integers, zero, and negative integers are numbers.
Constant	A number that has only one value or does not change within a given context. Often takes symbol , a, b, or c.
Variable	A variable is a type of quantity that can have a different numerical value depending on another variable. In bivariate data there is the <u>independent variable</u> , usually given an X value, and the <u>dependent variable</u> , the values usually read or obtained, usually with a Y-axis value.
Statistics	Uses results that are already known to understand a process that is not fully revealed.



Probability	Uses a knowledge of the process to determine the likelihood of a particular unrevealed future result.
Average	The 'arithmetic mean derived by taki"ng the <u>sun</u> of the obser- vation's divided by the number of observations in a particular sample. Sometimes called X. Be careful. using averages -- they might not be valid for the use involved.
Median	The middle observation in a set of data. If the data are arranged in the form of an ordered array (for example, in order of magnitude), the median is the half-way point: half of the readings are above and half of the readings are below the value. Sometimes called the 50th percentile or midpoint.
Decile Range	Dividing an ordered array of data by ten produces deciles.
Range	With a specified group the range is the largest value minus the smallest value of data.
Ratio	A comparison of one attribute of data with another attribute of the total. The expression clearly requires <u>what</u> is being compared to <u>what</u> . Often used for a small quantity of data.
Percent	The term literally means "number per hundred, " from the Latin word for one hundred. It is a fraction obtained by comparing the deviation with the standard and converting the ration to , "per one hundred. " Often used for large quantities of data.
Confidence	<p>A measure of how much confidence can be placed in the value of a sample. Confidence limits are placed (for example 90%) so that we can be (90%) sure that an interval, based on the sample, includes the universe values being sampled. Confidence means that after a sample is made and calculated you can say, 'I am certain that 9 out of 10 times (the 90% example) my calculated inference based on the sample is correct. " See the work sampling charts for use of the con- fidence limits.</p> <p>Common sense would indicate that data taken from samples cannot have 100% confidace. But the larger the sample, the better the chance, and confidence approaches 100 percent.</p>
Rardom Numbers	When a sample is taken from a universe or population, it is necessary to draw it with an <u>equal probability</u> that the sample represents the true population. It is important that every element in the universe have an equal chance of entering the sample. To aid this selection, random numbers are usually used to generate the selection criteria. Among others, random numbers can be obtained from tables or the telephone book.



SKILL IS PROFICIENCY AT FOLLOWING A GIVEN METHOD

'The narrowness of the above definition must be thoroughly understood. '. Method is excluded from the concept of skill by this definition. Most people associate skill with method and assume that the skilled operator will use the best method. However, modern industrial engineering recognizes no such thing as the one best method. There is the best method devised up to the present time, but with detailed study and advancing technology, any given method can be improved over and over again. You might look at some shipbuilding methods of today vs. **only a** few years ago for comparison.

Since a method is regarded as king in a continual state of evolution, method and skill cannot be tied together. An operator may be highly skilled at following a given method; the method itself may or may not be good. If it is considered good today, it may be considered poor six months later, when fresh developments have rendered it obsolete. It is very possible that an operator can become highly skilled at following a poor method.

Skill, or proficiency at following a given method, is influenced by both natural ability and experience, or practice. Studies have revealed large differences in the extent to which various individuals possess various skills or aptitudes.

Because of the skills and aptitude variation among individuals, it is necessary to recognize the skill possessed by an individual. Certain standards must be mastered to judge skills, but it is not particularly difficult to master them.

Studies of individuals' differences have shown that the difference between the best and the poorest individual in a large sampling can range as much as five or six to one for some of the basic aptitudes. The range within the shipbuilding industry is not this great, **however**, because the employment department will usually exclude those in the lowest ranges from the yard. Even if an occasional slipup occurs, performance on the job shows up the misfit very quickly. There is a process of natural selection going on at all times in any industrial organization; it has the effect of narrowing the range of skill in any shipyard, industrial plant, or business organization in general.

Skill, at any given moment, will not be varied deliberately by the operator. The operator may slow down or speed up, but this is changing effort. Fumbles and unnecessary motions may be introduced in an effort to extend the time for doing the job; this is changing the method. An operator's skill can be increased by practice, or it may be temporarily disturbed by illness or worry, but it will not be deliberately varied from moment to moment by an operator.

The skill which is considered useful for practical purposes is subdivided into six general classes: poor, fair, average, good, excellent, and super skill. Skill below poor will be excluded either at the employment office or on the job. Below average skills, if they persist after proper training, are **usually not** tolerated in a well-managed shipyard.



The characteristics of performance which place an operator within a given skill classification are quite easily recognized by an experienced observer. All of these characteristics may not be observed with any one operator, but enough of them are usually encountered to make the worker's level of skill easy to recognize.

Poor Skill

An operator who works at the poor skill level is usually a new worker or one who is naturally unfit for the work. In the case of the new worker who has not had any previous experience on the job, lack of knowledge is evident. Lack of experience makes it necessary for him or her to stop and to think what the next move is going to be. Even after deciding the next move, the operator moves with an uncertainty that is quite pronounced. If an error should occur, it will lead to confusion and could result in more and greater errors. The poor operator lacks confidence which will be gained by experience.

When the skill of an operator is considered to be poor after having sufficient time to learn the job, he or she is a misfit. The operator knows what to do but does not seem able to do it with ease. Movements are clumsy and awkward. Mind and hands do not coordinate and before making a move, the operator must stop to consider whether or not it is right. The worker, with all seeming care and consideration, turns out an inferior quality of work, makes many mistakes, and spoils more work than those with more skills.

Fair Skill

The worker considered to possess fair skill could be a misfit who has been doing the job for so long that he or she has been able to overcome some natural handicaps and, as a result, has been able to rise from the poor skill level. This case is uncommon, however, for if a worker is truly a misfit, dissatisfaction with the job will result and the worker will quit before working long enough to develop fair "skill,

More often, the fair worker is comparatively new but has been doing the work long enough to follow the correct operation sequence without an undue number of fumbles or mistakes. Workers performing at the fair skill level are still somewhat clumsy and uncertain in their motions, but they have a definite idea of what they are doing. They have become familiar with their place of work so they are not easily distracted. They will become familiar with the location of cutting or grinding tools, machine control levers, and supply bins so time is not wasted searching for tools or materials.

The fair skill operator has sufficient knowledge of the work to plan ahead somewhat. It is not necessary between operations to think what must be done next. At the same time, the fair worker lacks total self-confidence; he or she still is not entirely familiar with the work.

On work which requires a high degree of manual dexterity, the operator at the fair skill level will find it necessary to spend some time repairing mistakes that were caused by lack of Skill"



Average Skill

The operator who possesses average skill is the one most discussed and the one to whom all others are compared. This is the worker who has been on the job long enough to be considered proficient in the work. However, the average operator has not been doing the work long enough to gain the proficiency that results only through much experience.

The average worker performs the work with reasonable accuracy and has self-confidence. This operator has passed the learning stage and is now in a position to be considered a full-fledged artisan in his line of work. The average operator will follow a set procedure regularly and will make few mistakes, if any. Experience has taught the operator the advantage of planning ahead.

Average workers understand their tools and equipment and they are able to handle them properly. They have lost that clumsiness and uncertainty of movement due to inexperience. Their minds and hands coordinate well so that hesitations are significantly reduced.

Average operators do work according to specifications, but they also think out things for themselves. Workers who possess average skill turn out work which is satisfactory in every respect. They may appear a little slow in the speed of their motions , but they do give a satisfactory performance.

It must be clearly understood that "average" skill means an average that has been established by definition . It is not a mathematical average. Any given group of workers may all possess greater than average skill. This occurs frequently in a Well-managed and established shipyard where labor turnover is low. However, in a new yard, all of the workers could conceivably be below average. In other words, the average skill of a given group has no relation at all to the average skill as established by definition. Average skill by definition describes a fixed level which is the same in every industry and on all operations.

Good Skill

The operator whose skill may be considered as good is noticeably better than the average operator. The operator with good skill is intelligent and possesses high reasoning ability. This worker will produce more and better work than the worker of average skill with seemingly less effort.

Workers with good skill are fairly quick in their motions and are sure of themselves. They will turn out good work and may be counted on to do it in less than the allowed time unless outside troubles develop. This worker has a good knowledge of all tools, equipment, and materials required in the performance of the job and uses them to good advantage.

Operators who have good but not outstanding natural ability develop good skill after being on the job long enough to learn it thoroughly.



Excellent Skill

An operator whose skill may be considered as excellent is distinguished by precision and certainty of action, speed and smoothness of performance, and self-confidence. This worker is definite and certain of the work and does not make mistakes. He or she understands machines and tools pertaining to the work and uses every available advantage. Mind and hands seem to coordinate automatically and the operator seems to work without effort. The excellent skilled worker is thorough and accurate and produces a good quality far above those less skilled.

This operator is fitted for the work and has gained the knowledge and confidence which is to be expected from one who has had much experience in the same class of work.

Super Skill

The super skilled operator is not common in the shipbuilding industry or in industry in general. Super skill comes from many years at the same line of work. The fact that methods and equipment change frequently as new and better means are devised prevents workers from becoming this highly skilled. In the few cases where the nature of the work is unvarying year after year, workers who may be considered as super skilled might be found, although these are the type of workers who tend to be promoted out of repetitive tasks.

The super skilled operator has all of the characteristics of the worker with excellent skill, but developed near perfection. This worker knows the job so thoroughly that motions are as quick as those of a machine. The super skilled worker does not have to think about the work but performs the task automatically. Hands seem to fly to the proper places without conscious effort. Motions are so smooth and rapid that they are difficult to follow. One operation blends so smoothly into the next that even an experienced observer will have to watch very closely to determine the point where one part of the operation ends and another begins.

Summary of the Levels of Skill

Poor Skill: New worker or misfit - Unfamiliar with the work - Uncertain of proper sequence of operations - Hesitates between operations - Makes many errors - Movements clumsy and awkward - Does not coordinate mind and hands - lacks self-confidence.

Fair Skill: Misfit on the job for a long time - Comparatively new worker - Follows proper sequence of operations without much hesitation - Somewhat clumsy and uncertain but knows what to do - Fairly familiar with equipment and surroundings - Plans ahead to some extent - Lacks total self-confidence - Loses time due to own blunders - Gets same output with less effort than poor worker.

Average Skill: Works with reasonable accuracy - Self-confident - Proficient at the work - Follows a set procedure without appreciable hesitation - Understands tools and equipment - Plans ahead - Coordinates hand and mind - Appears a little slow in motions - Turns out satisfactory work.



Good Skill: Noticeably better than ordinary run of workers - Markedly intelligent - Good reasoning ability - Hesitation entirely eliminated - Needs little supervision - Works at steady pace - Works correctly to specifications - Can instruct others less skilled - Motions well-coordinated and fairly quick.

Excellent Skill: Precision of action - Speed and smoothness in performance - Thoroughly familiar with work - Makes no mistakes - Works accurately with little measuring or checking - Operates machine or tools to best advantage - Works rhythmically and with coordination - Works fast without sacrificing quality - Has total self-confidence - Possesses high natural aptitude for work at hand.

Super Skill: The operator of excellent skill perfected - Has been at the work for years - Naturally suited to the work - Works like a machine - Motions so quick and smooth that they are hard to follow - Does not seem to think about the job - Conspicuously the best worker of all.



EFFORT IS THE WILL TO WORK

Effort has nothing to do with foot pounds of exerted force or, pounds per square inch. Effort is related to the zest or energy with which a task is undertaken. Effort can be controlled by the worker at all times, and poor effort is given because, for one reason or another, the worker wants to give it.

The amount of the effort which operators put into their work depends, in part, upon their attitude toward the company and company policies. Some of the other factors which influence effort are health, physical condition at the moment, interest in the work, general labor attitude at the time, working conditions, mental condition, and distracting elements.

The skill of the supervisor also influences hourly-paid workers. As the foreman communicates company plans and goals, motivates, and assigns work, an operator's willingness to expend effort is greatly influenced. In fact when the analyst observes an unusual level of good or poor effort among a group of workers, the level of skill of the foreman may be the reason.

Effort can range from pure idleness up to an excessive working pace which is unwise to maintain. The range for use in the shipbuilding industry or industry in general however, is divided into six general classifications: poor, fair, average, good, excellent, and excessive. The characteristics of each range will be described here.

Poor Effort

A poor effort may be given (in theory) by an operator possessing any of the six degrees of skill; however, it is more commonly found in company with the lower skill levels. An operator who has remained on the job long enough to develop high skill usually has developed an interest in the work and a practical understanding of company policies. The worker of low skill, being either a newly hired employee or else a misfit (and hence dissatisfied with the job) is likely to give a poor effort. A poor effort may be caused by lack of interest. It can also be deliberate and malicious, however.

Poor effort can readily be detected by an experienced observer. It usually takes one of two forms. It may take the form of a lackadaisical, dispirited attitude, accompanied by an obviously slow working pace. It can also take the form of a great deal of unnecessary work undertaken with a frantic display of energy.

The first form mentioned -- the slowed-down work pace -- is easily recognizable. The operator performs the work in slow-motion style, and obvious attention is concentrated on holding back as much as possible without actually stopping. The lack of effort is unmistakable, and the observer must decide whether or not the slowdown is great enough that it actually carries the performance below the poor level.



The other form of poor effort, while also readily detected by the experienced observer, is more amusing to observe, particularly if it is carried out cleverly. The operator introduces all sorts of unnecessary work and attempts to make the job seem different and more difficult than it actually is.

Many trip for tools are made when only one trip is necessary. The same is true of materials and other accessories, for instead of analyzing the job and getting everything required in the fewest number of trips, the operator finds an excuse to make a trip for each separate item. This not only requires the additional time to make the extra trip, but it also extends the time for doing the other work by continually stopping and starting. Hence, the operator does not get a chance to get into the swing of the work. The poor effort worker finds it necessary to stop work an unusual number of times to talk to another worker, get a drink, or do some other personal task. Interest is shown in things which are apparently out of the ordinary. Unusual "trouble" may develop with tools or the materials.

This worker makes many false and unnecessary motions. Many mistakes are made and the operator finds it hard to do anything right the first time. Sometimes the work will be finished to a degree of accuracy that is not necessary and that will not be maintained. This operator resents any suggestions for improvement and intimates that they have been tried before unsuccessfully. All of these attempts to extend the time are quite obvious to the experienced observer who has studied the operation in advance.

Fair Effort

The operator who exerts a fair effort has a somewhat more reasonable attitude toward work, but still exhibits a number of the same tendencies shown by the operator giving a poor effort. He or she takes little interest in the work and seems to regard it as a necessary evil.

An operator performing at the fair effort level performs fewer unnecessary operations although some will be present. The worker tries to go about the job in some systematic way, and generates the impression of really trying to do a fair amount of work. It is readily apparent that the operator is not putting forth best effort, but at the same time, is not resorting to the extreme time-killing practices of the operator giving a poor effort.

Average Effort

Average effort is the borderline effort between fair and good. It is the effort to which all others are compared, and yet it perhaps the hardest to define specifically. It is a little better than the fair effort level and still a little less than the good effort level.

The average effort operator works steadily and with a fairly good system. Lost motions are reduced and the operator appears to take some interest in the work. The average effort level has some of the characteristics of both the good effort level and the fair effort level. It is an effort level that most operators can maintain day after day without undue fatigue.



Good Effort

A good effort operator works steadily and systematically and does not lose time doing operations foreign to the work. This operator takes an interest in the work and takes pleasure in turning out good work. An operator at the good effort level works steadily at a pace which can be maintained day after day and week after week. Operators at this level are conscientious about their work and when not under observation do not try to use shortcut methods that detract from the quality of the finished product.

Excellent Effort

An excellent effort differs from the good effort in several respects. Operators exerting an excellent effort work fast and use their heads as well as their hands. They work with a will and make their minds direct their efforts to the best advantage. They take a keen interest in the work and readily follow any good suggestions others might make. They are also on the alert for better ideas of their own.

This worker reduces false motions as far as skill permits and thinks ahead. This operator knows just what to do before it is time to do it, and when the time comes, does it with enthusiasm.

Most workers cannot keep up an excellent effort week in and week out, but can keep it up all day and perhaps for several days. A worker who usually gives a good effort will, on some days when feeling particularly fit, give an excellent effort. It may be that a keen interest in a particular job causes the worker to put forth an excellent effort.

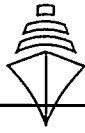
Excessive effort

Excessive effort is just as its name implies --excessive, or too much! It is given by some workers who cannot work normally when anyone is watching them. Many times excessive effort is due to a tendency to show off. They extend themselves to a pace which they could not possibly keep up for over an hour or two. A few quiet words might calm the worker down to a more reasonable effort level. This is often advisable, for excessive effort will very likely affect the operator's skill level. In consideration of effort alone, the excessive effort is best from every standpoint but that of health.

Summary of: the Levels of Effort

Poor Effort: Obviously kills time - Lacks interest in work - Works slowly and appears lazy - Attempts to extend time through improper method by: (a) making unnecessary trips for tools and supplies (b) having poor setup; (c) doing work more accurately than necessary; (d) purposely using wrong or poor tools.

Fair Effort: Same general tendencies as Poor effort but of lessened intensity - Accepts suggestions grudgingly - Attention appears to wander from work - Possibly affected by late hours, dissipation, or mental worries - Puts some energy into work - Some improper methods used are: (a) fairly systematic but



does not always follow same sequence; (b) somewhat too accurate; (c) makes jobs unduly hard; (d) does not use best tools; (e) seems purposely somewhat ignorant of the work at hand.

Average Effort: Better than fair, poorer than good - Works steadily - Accepts suggestions, but makes none - Seems to hold back effort - With respect to method; (a) has good setup; (b) plans ahead; (c) works with good system; (d) reduces lost time.

Good Effort: Little or no lost time - Takes an interest in the work - Works at best pace suited for endurance - Conscientious about work - steady and reliable - Follows accepted methods.

Excellent Effort: Works fast - Uses head as well as hands - Takes keen interest in work - Receives and makes many suggestions - Cannot keep up effort more than a few days - Endeavors to show superiority - Uses best equipment and methods available; (a) reduces false motions to a minimum; (b) works systematically to best of ability.

Excessive Effort: An extended pace impossible to maintain steadily - May be "showing off" - Best effort from every standpoint but that of health.



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THE LAWS OF MOTION ECONOMY

Principles of Motion Economy

The trained time study analyst does not go about an analysis of methods and motions haphazardly, but is governed and guided by certain principles of motion economy. These fundamental principles are called the five Laws of Motion Economy.

1. When both hands begin and complete their motions simultaneously and are not idle except during rest periods, maximum performance is approached.
2. When motions of the arms are made simultaneously in opposite directions over symmetrical paths, rhythm and automaticity develop most naturally.
3. The motion sequence which employs the fewest basic divisions of accomplishment is the best for performing a given task.
4. When motions are confined to the lowest practical classifications, maximum performance and minimum fatigue are approached.
5. When conditions are the same, the time required to perform all basic divisions of accomplishment is constant for any given degree of skill and effort.

Law 1

When both hands begin and complete their motion simultaneously and are not idle except during rest periods, maximum performance is approached.

When both hands are working, it is desirable that they begin and complete their motions at the same time. In this way, a working rhythm is developed which carries the worker along toward maximum performance. If only one hand is working and other is idle, only a part of the maximum possible efficiency is obtained. When one hand is working, the idle hand is not relaxed, and it does not rest. In fact, it is usually fatiguing to hold one hand motionless while the other is working. On classes of work where it is not possible to do the same thing with each hand at the same time, idle periods often occur as the operator works first with one hand and then with the other.

Law 2

When motions of the arms are made simultaneously in opposite directions over symmetrical paths, rhythm and automaticity develop most naturally.

Motions of the arms should be made simultaneously if Law 1 is not to be violated. They should be made in opposite directions from axis of the body. When this is done, one arm balances the other, and no body movement is necessary. If the arms are moved in the same direction, either to the right or to the left of the body, the whole trunk has to be shifted to balance the weight of the arms. This brings a number of body muscles into play, and on repetitive work, increases



fatigue noticeably. If the arms must be moved in the same direction, they should move away from and toward the body rather than to the right or to the left, as the body can more easily balance a motion of this kind.

Motions should be made over symmetrical paths because most human beings are so constructed physiologically that one side of the body wants to work in unison with the other doing similar things. If the workplace is laid out so that the right hand must follow a triangular path while the left hand is following a circular path, the operator will have difficulty working in accordance with Law 1. There will be a tendency for both hands to move either along the triangular path or the circular path. To overcome this, the operator is likely to work first with one hand and then the other. This tendency toward symmetrical movements of the two sides of the body has an important bearing on safety. If unsymmetrical paths must be followed in moving near machinery, care should be taken to see that the tendency to change over into symmetrical paths will not carry the hand into a danger zone.

Law 3

The motion sequence which employs the fewest basic divisions of accomplishment is the best for performing a given task.

Performing a basic motion consumes a certain amount of time. Therefore, every basic motion made should be analyzed with the idea of eliminating it or combining it with another. When the work is performed with fewer basic motions, it will be performed in a shorter time. Furthermore, as the number of motions decreases, the fatigue per piece will decrease. There may be a few isolated cases where several short motions will consume a shorter time than a lesser number of longer motions, but this is rare enough to be considered the exception. Usually, the path of the lesser number of motions can be rearranged so that the time for performing them is reduced below the time required for the greater number of shorter motions.

Law 4

When motions are confined to the lowest practical classifications, maximum performance and minimum fatigue are approached.

All physical motions are divided into five classifications according to the bodily parts involved in making them. They are as follows, arranged with the most economical and least fatiguing first:

1. Finger motions
2. Finger and wrist motions
3. Finger, wrist, and forearm motions
4. Finger, wrist, forearm, and upper arm motions
5. Finger, wrist, forearm, upper arm, and body motions

The fifth class requires a change of posture, while the first four do not. Motions of the first class are performed most quickly and with the least expenditures of energy, while motions of the fifth class obviously require more time and effort to perform. For example, it is possible to pick up a small part from a table, using only finger and wrist movements, in a fraction of the time



required to turn around and extend the arm to pick up the identical part. Hence, it is always desirable in arranging the workplace and in determining the best method for doing the work to have as many of the motions as possible in the lower numbered classifications.

This should, of course be interpreted with common sense. It might be possible, by exerting a great effort, to lift a heavy object an inch or so with a finger movement, but the same object could be lifted the same distance in less time and with far less fatigue by a finger, wrist, and forearm movement. In actual practice, there is no difficulty in recognizing the lowest practical classification.

Law 5

When conditions are the same, the time required to perform all basic divisions of accomplishment is constant for any given degree of skill and effort.

The word "conditions" is used to cover all factors which can possibly affect the time required to perform a basic motion. It embraces not only such factors as light, heat, ventilation, and so on, but also such factors as nature of the part with respect to size, shape, weight, distance moved, material and inspection, and accuracy requirements. For example, among the conditions which affect the time for performing the operation of lifting a weight of ten pounds a distance of one foot include temperature, location of the lift (near the floor, waist high, overhead), material and condition of the surface grasped (rough or slippery) , and bulk. But for any given set of conditions, any two workers will take the same time to perform the operation if they are working at the same level of performance. This concept is simple, but it forms the basis for all time allowances. If it were conceivable that an operator working at a given performance level would perform the same operation under the same conditions in a different length of time on one occasion than on another, then it would be impossible to establish time standards as we know them. By eliminating through standardization all or nearly all variations in conditions, it is possible to establish accurate performance standards.



THE TRADITIONAL LAWS OF MOTION ECONOMY REVISED FOR SHIPYARD HULL CONSTRUCTION

As you read earlier, several pioneer industrial engineers developed laws of motion economy. But just as MTM-1 is hardly applicable to shipyard work, neither are the laws of motion economy. As work measurement is being done in MOST, MAXI-MOST, or MEK/UAS, these motion economy principles need a similar revision.

These typical laws of motion economy are meant for light industry associated with incentive pay and relative high-volume production at a fixed workplace. The work goes to the worker rather than the typical shipyard way - where the worker goes to the work. Principles meant for high volume/small parts (using a "micro" approach) probably won't work for shipyard low volume/large parts.

Without compromising the classic laws of motion economy, or excepting the few places in a shipyard where they may be applied profitably, the twenty-two laws of motion economy with a few exceptions have limited application in shipyard hull construction.

But the exceptions are worth looking at. Three principles of motion economy for shipbuilders follow:

1. Hand and body motions should be made at the lowest classification and fewest in number.

Using lower level movements, perhaps the most fundamental of the laws of motion economy, is difficult to do in a shipyard. Prof. Ralph Barnes points out that "body movements are time-consuming and result in high physiological (fatigue) costs as well." But the "geometry" of shipbuilding is more like building construction: instead of work flowing to the operator at a fixed workplace, most jobs involve the operator going to the work.

The work involves a lot of body motion with walking, bending from the waist, kneeling on both knees (and working in that position), and rising from kneeling on both knees. We have a number of body motions not even listed in MTM-1 body movements such as squatting, arise from squatting, sideways move while squatting, and lying down.

Even with this "problem geometry," improvement can be made. Most of these high-time motions can be reduced in classification and particularly in number.

Less walking, less squatting, more work when in position -- all these can contribute to motion economy.

2. The workers, tools, fitting aids, and supplies should be organized and positioned for efficient operation.

To a certain extent this relates to worker skill, but expert workers are often characterized by always having their tools in a convenient, handy place. As they move about a unit they efficiently move their tools at the same time so that extra, long, or inefficient moves are minimized.



Encourage the use of "standard operating procedures" for transporting, positioning, and using tools.

3. Power tools should be substitute for muscle power whenever possible.

While this is not exactly motion economy, moving heavyweight workpieces around by muscular power is slow, fatiguing, expensive, and should be avoided.

Modern shipbuilding is characterized by using hydraulic power units, mechanical hoists, block and tackles, power cranes, etc. ; the proper use of mechanical aids presents a constant opportunity for better methods.

Whenever you see an operator repeatedly using his body and large muscles to accomplish a task, look for a chance to use a machine. The old saying of "waste not, want not" applies in shipyards, too. Wasted time is gone forever and shipyards cannot afford any wasted time.



MOTION ECONOMY DEVICES FOR GENERAL (LIGHT) MANUFACTURING

The laws of motion economy for general manufacturing can be adapted mechanically into what is called the motion economy device. These devices have proven themselves in many workplace layouts in general light manufacturing. Among the more familiar are quick-acting clamps, stops, rotary type (or "lazy Susan") fixtures, air cylinder attachments, motion economy bins, foot pedals, ejectors, and drop delivery devices. Many of the motion economy devices come under the heading of assembly, positioning, or holding fixtures. These vary in design from the simple stop attached to the table to a completely automated production line. Here is a list of motion economy devices and typical examples of each.

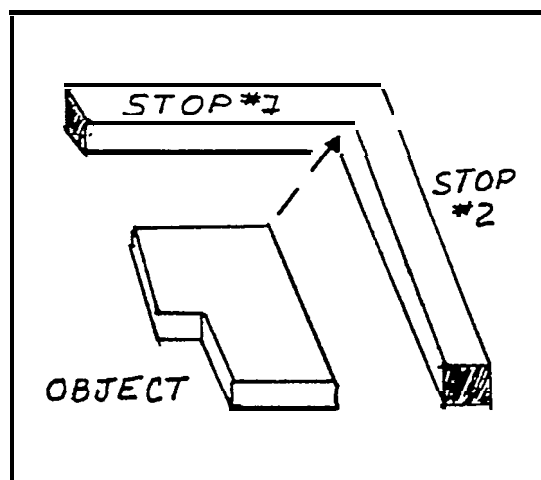
Quick-Acting Clamps

A quick-actining clamp can be incorporated into various machine designs. The function of a quick-acting clamp is to provide a quick and efficient way of holding a part at a location while operations are performed with, on, or to the part. Many times it is necessary to hold two parts together while they are being joined or connected. When the parts will adapt easily, a quick-acting clamp will provide the accurate holding necessary, while still using the minimum amount of activating motions. Many times on milling or drilling operations a part is held in position by means of a quick-acting clamp. The part can be clamped and held quickly as well as king released quickly. Quick-acting clamps are easily obtained and inexpensive.

Stop3

A stop is a device used for locating material at a predetermined position in order that work can be performed on the material at that position. A part is moved against a stop with far less motion control than would be necessary if the operator were required to place the part accurately. A motion requiring less control is performed in less time, so providing proper stops will speed up an operation by reducing the time required to perform it.

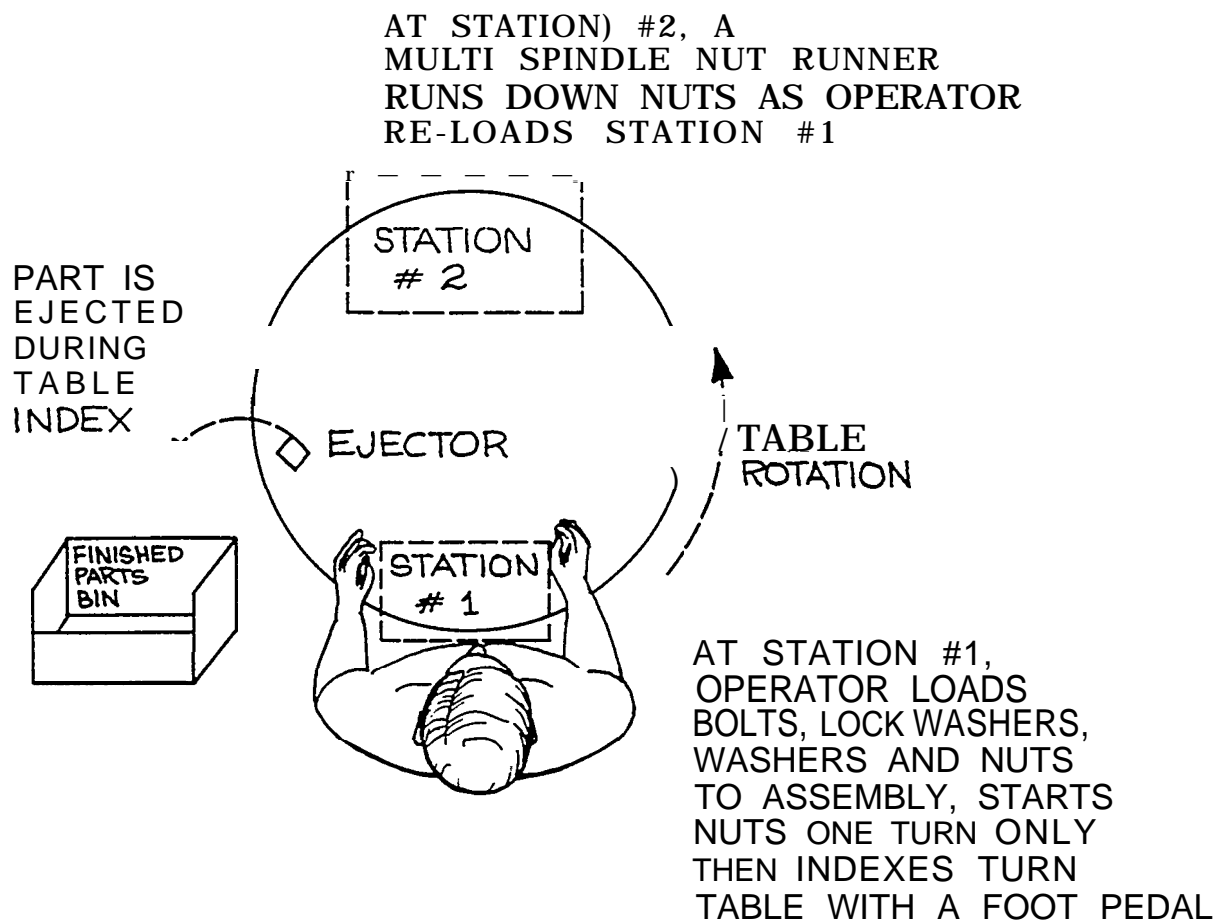
In this example, two stop are used to guide the object to a predetermined location.





Rotary Fixtures

Rotating fixtures, or "lazy Susan" fixtures, are designed for operations involving machines or welding. Rotary fixtures are also used in combination with air-cylinder installations. Rotary assembly fixtures have been designed to be used by only one operator with several operators depending on operation sequences and length of operation cycles. An ejection mechanism can be incorporated into the design of a rotary assembly fixture. The sketch illustrates the motion economy benefits that can be obtained by using a rotary assembly fixture.



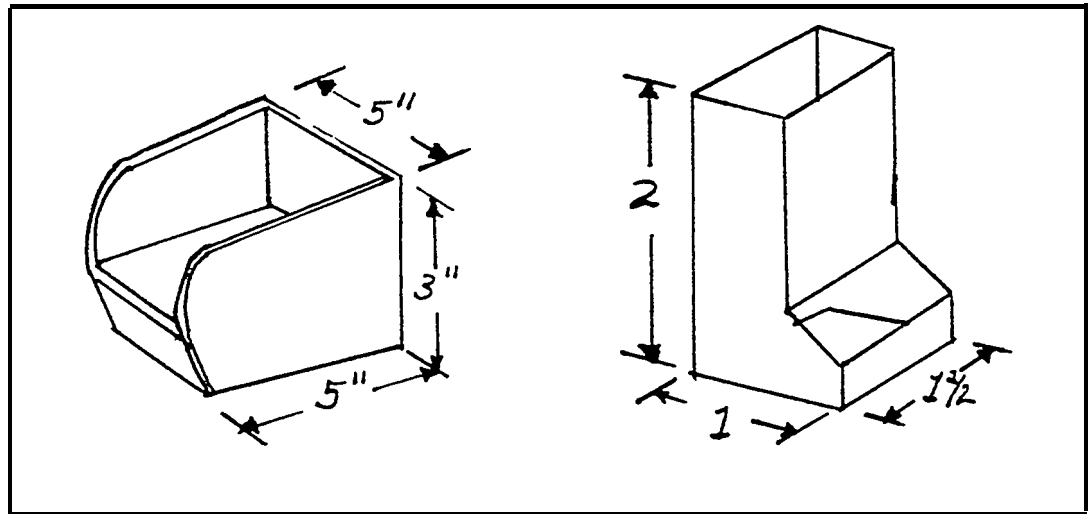
Rotary Assembly Fixture



Hoppers and Motion Economy Bins

A hopper or bin should be used as a storage device but should also be designed to deliver the material at a predetermined location to allow a normal grasp by the operator. Bins are made of various materials including plywood and sheet metal.

A hopper usually employs the use of gravity to feed the parts to a predetermined location. Hoppers are usually constructed from plywood or sheet metal, although plastic hoppers are now available and are becoming common.



Typical Plastic Assembly Bin

Typical Hopper

Assembly bins usually are smaller in size than a hopper and are used in connection with smaller assembly operations that require smaller parts. The bins usually are arranged in a semicircular pattern to allow the operator to perform the operation within the normal work area.

Foot Pedals

A foot-operated pedal can provide an easy way of activating a mechanism, for holding or releasing a part, or operating wide variety of assembly mechanisms. The amount of required pressure for performing the operation must be considered when a foot pedal is designed. The main function of a foot pedal is to free the hands for more useful work. Since the leg is a stronger body member than the arm, a foot pedal also will reduce fatigue.



Swivel Fixtures

Swivel fixtures are built on the principle of the ball and socket joint. The main advantage of the swivel fixture is flexibility. It may be positioned to put a part exactly where the operator needs it and holds the part securely in that position. The swivel fixture may be adjusted to utilize proper light, or can be adjusted for inspection operations. It can be held at various angles for testing as well as positioning the part in the easiest assembly position so that a two-handed motion pattern can be used.

Drop Delivery Methods

One of the functions of "drop delivery is to remove a finished part from the work area. Drop delivery chutes can reduce or eliminate motions. The simplest form of drop delivery is a hole in the work bench. The finished part falls through the hole into a tote pan. More delicate material can use the principle of drop delivery by sliding to a tote pan from a chute. "Drop delivery does not necessarily mean dropping a part downward. A retractable recoil hose, for example, pulls the hose up out of the operator's way when it is not being used. This is still an example of "drop delivery, " since the operator simply "drops" the hose by letting go of it; no further attention is required.

Interchangeable Table Tops

Many times assemblies are required that are not repetitive enough to justify a permanent location. However, special workplaces might be needed for this assembly. The use of removable table tops will provide a quick change from one workplace to another. Interchangeable table tops can allow the performance of several operations at only one work station.



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DEVELOP THE IMPROVED METHOD

After the method to be studied has been selected, the gathering of facts on the current practices begins. This is the very first step in developing the improved method. You must first know how the operation is currently being performed before good solid suggestions for improvement can be made. The collection of facts will provide the data that once analyzed will provide the clues for improvement. During this phase, suggestions on how to improve the operation should be solicited from the people performing and supervising the operation. The more views received on how the operation can be improved, the better the chances of success with the final proposed method. The person actually performing the work will usually have the most valuable input for improving the operation. He also can make your new method work or not work.

The second step in developing an improved method will be to examine all the facts that have been collected. Use the question technique by asking:

- . What should be done?
- . Where should it be done?
- . When should it be done?
- . Why should it be done?
- . Who should do it?
- . How should it be done?

Once these questions have answered and the pertinent data have been pulled out, the next step will be to apply the laws of motion economy to the data. This process will help in developing the rationale for selecting the final alternatives for improvement.

The next step will be to set up the data in such a way that an easy comparison can be made. There are a number of ways to compare using charts. One of them is to use a flow process chart, so that the proposed method can be compared with the original method. This will provide a check to make sure that no point has been overlooked. It also enables a record to be made in the "summary" of the total number of activities taking place under both methods, and the savings in distance and time which may be expected to accrue from the change.

The final step in the development of an improved method is to put it into a brief report for presentation. Keep it short with a minimum amount of detail. you can always go back to your files to answer detailed questions, that is, if you have done your homework. The report should start with a description of the current operation that is being considered for change. Then write a description of the proposed changes and the benefits of making such a change. Include a comparison chart of present versus proposed. It should include:



- Manning
- Man-hours
- output
- Facility Requirements
- Tooling
- Total Costs

The report should conclude with the projected savings and implementation cost of making such a change. The case study section of this text contains a typical methods improvement report.



MATERIAL HANDLING

Material Handling in Shipyards

The types and varieties of material handling devices used in a shipyard are just as varied as the types of shops that make up a shipyard. In shipbuilding, the movement of materials can easily account for up to half of the production activity. Therefore, handling activities are excellent candidates for analysis. It should be remembered that material handling only adds cost to the end product and does not add substance to the product. Therefore the ideal shipyard would not have any material handling. In reality this would never occur, but material handling can be reduced to a minimum and this in turn results in reducing ship construction costs.

Equipment Available

The material handling equipment in a shipyard is so varied it would be very difficult to establish a complete list. However, a skeleton list has been developed with four categories covering the majority of equipment.

Trucks

Forklift
Straddle lift
Side loader
Pickup truck
Self-propelled transporter
Flatbed trailer

Cranes

Jib
Derrick
Whirley
Bridge
Gantry
Goliath
Mobile

Conveyors

Monorail
Power roller
Gravity roller
Power chain
Power belt

Miscellaneous

Barge
Rail car
Hard truck
Hand-operated lift truck
Man
Bike



Utilization

All the techniques mentioned in this workshop can and should be used to evaluate the utilization of material handling equipment.

An excellent way to start a material handling analysis is with a questioning attitude applied to the three M' s of material handling: MATERIAL, FINE, and METHOD. The first question that should be asked is WHY.

- . Why is the material being moved? Is it necessary or unnecessary? If you find it is an unnecessary move, take action to correct the situation; if it is necessary, proceed to the next set of questions.
- . What material is to be moved? What are its characteristics? Is it a solid, liquid, or gas? What is the size, weight, shape, and quantity of the material?
- . Where and when is the move?
Where is the source of material?
Where is the destination?
When is the material needed?
- . Once it is understood what is to be moved and where and when it should be moved, then the method of transporting can be addressed by asking how and who.
Who is to do the moving? Is it the operator, the area material handler or the Transportation Department?
How is the material to be moved? What equipment is currently available to make the move? Can new equipment be justified to do the job more efficiently?

Remember, each question (what, where, when, who, and how) should all be preceded by WHY.

After you have determined the materials to be moved, where the material will be moved and how it is to occur, you more than likely will be faced with several additional questions. Do we have the right number and type of the required material handling equipment? Are we utilizing the equipment we have effectively? If not, are there problem areas that can be rectified to improve utilization? Such question can be answered by using work sampling as demonstrated in the case study presented here.

Case Study

A request was recently made by the Transportation Department of a shipyard for five additional 15,000 # forklifts. The Transportation Department indicated that they could not keep up with the demand for material to be moved. Whenever such a request was made in the past, the equipment was purchased with little or no evaluation of the current usage of the existing equipment. As a result of this, the forklift fleet has grown to seventy units, fifty of which are assigned



to the Transportation Department. Management is on an austerity drive and would like to deny the request; however, they do not have sufficient information to do so. They are concerned that if the forklifts are not purchased, production will suffer. After several days of kicking around the request, management decided to ask the newly-established Industrial Engineering Department if they could evaluate the request for forklifts to determine if they were really required.

This was the first time such a request was made for equipment utilization. In order for the Industrial Engineering Department to establish credibility in the yard, the analysis would have to be accomplished within a short time frame and still maintain a high degree of accuracy. With this in mind, work sampling was chosen as the tool for the analysis. **It was felt that an accuracy of $\pm 5\%$ at a 95% confidence level would be acceptable;** a preliminary work sampling study was taken before the initial study to determine the desired number of observations. The preliminary study indicated that approximately 1,600 observations would be required to achieve the desired accuracy, and on the average of 50 observations per trip could be made. With this information, a work sampling schedule was set up for a three-week period with three trips per day. The telephone book was used to generate the random times for the sample trips.

An observation form was designed so that the activity of each vehicle could be recorded when the first sighting occurred. The activities were assigned categories as follows:

I. Utilization Activities

- A. Moving with a load
 - Transporting material
 - Pulling "mule train"
- B. Get or aside load
 - Moving into position to get or aside load
 - Loading or unloading "mule train"
 - operator of lift locating material
 - Operator doing paperwork
- c. Moving without load
 - Lift in motion without load

II. Nonutilization activities

- A. Idle
 - Operator sitting on lift and not in motion
- B. Lift minus operator
 - Lift by itself and operator not in the general area
- c. Talking with other worker
 - Conversation not related to work



After the three-week period ended, the recorded data was evaluated and the study indicated that the yard-wide utilization of the forklifts was at 50 percent. This was established with a confidence level of 95% and an accuracy of 24% of the predicted true value ($\pm 4.0 \times 50.0 = 2.0\%$) being between 48% and 52%.

Each activity category was also evaluated and developed. Percentages of time spent on each follow:

Utilization Activities	Moving with a load	16.7%
	Get aside load	26.7%
	Moving without load	6.6%
Nonutilization activities	Idle	16.6%
	Lift minus operator	23.6%
	Talking with other worker	9.8%

The study data was also compiled to project forklift utilization by day of the week (Chart A) and by time of the day (Chart B). The percentages of utilization per day were as follows:

Monday	54.7%
Tuesday	51.0%
Wednesday	51.5%
Thursday	47.1%
Friday	46.0%

The data projected on the time of day utilization chart indicate that the day starts at 49.5% and peaks in the morning between 8:45 and 9:00 at 56.5%; then the trend is downhill till lunch at 46.8%. After lunch the activity starts off at 55.8% but then continually declines to 36.2% at the end of the shift.

The data were also listed by vehicle. This information indicated utilization by forklift. The lowest utilization was the Boiler Shop forklift at 10.0% and the highest utilization was Lift #75 in the Transportation Department at 85.0%.

A forklift departmental assignment area was developed to pinpoint low and high utilization areas. The Transportation Department was high at 60.0% and the Boiler Shop was the lowest at 10.0%.

The data was then split by vehicle type and capacity in an attempt to determine capacity range requirements. The most heavily used capacity range was 15,000 # at 70%. This indicated the possible reasoning behind the request for additional 15,000 # lifts.



The data was compiled on transportation forklifts in a category of radio vs. non radio-equipped lifts. The utilization of lifts with radios was a 70% while lifts without radios was at 60%, indicating a definite preference in using forklifts with radios.

The study indicated a number of areas for improvements:

- A. It was noted that three show in the same general vicinity had their own assigned lift and in fact one shop had two. Not one of the lifts was used more than 15% of the day.

It was recommended that the four forklifts used to support those shop be reduced to one. This would increase that one forklift's utilization to 65%,

- B. It was determined that the Material Handling Departments utilization of its five forklifts was at 38%. This projects into a weekly usage of 15.4 hours out the possible 40 hours available. There was also an indication that the man-load requirement in this area has been over projected.

To project a solution, the 38% utilization figure was broken down to look closer at the actual activities.

Utilization Activity	Utilization (%)	Daily Req. (Hrs.)
Moving with load	4.0	1.8
Get/aside load	30.9	12.4
Moving without load	3.1	1.3

This indicates that a forklift is required 3.1 hours per day to move material. The get/aside load activity mainly consisted of hunt and pick, which did not require the use of a forklift. The Material Handling Department could function very well with two lifts.

- c. The study indicated that the Transportation Department's forklifts with radios had a much higher utilization (70%) than those without (60%) . By outfitting the non radio forklifts with radios, two forklifts could be eliminated. This would drastically improve utilization of forklifts assigned to the Transportation Department.

The conclusion is that no more forklifts are required, therefore the purchase request for five new forklifts will be cancelled. It was also established that eleven forklifts would be eliminated from the current fleet. This was a savings that was not originally anticipated and only would have been detected through a materials handling analysis.

CHART A

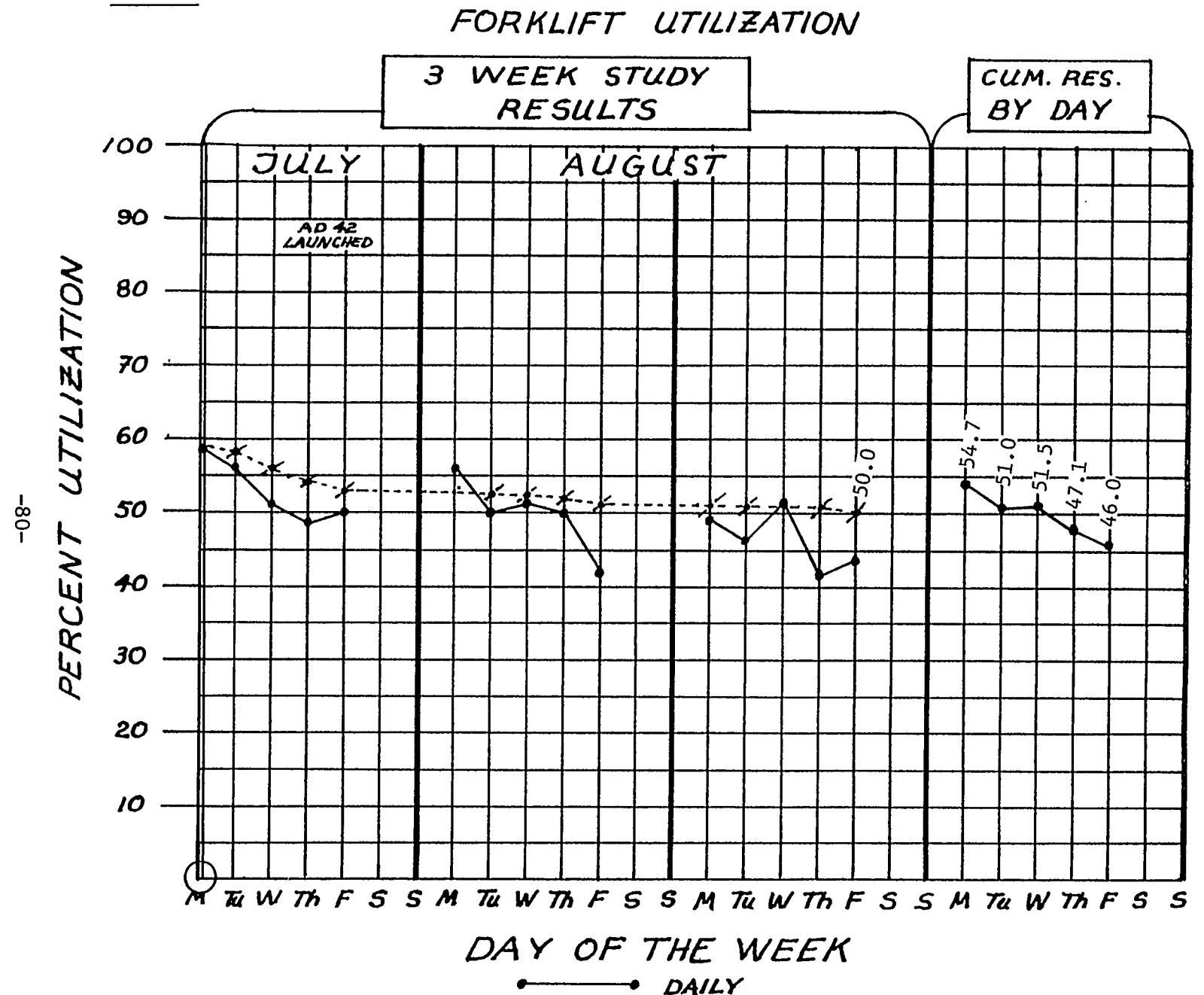
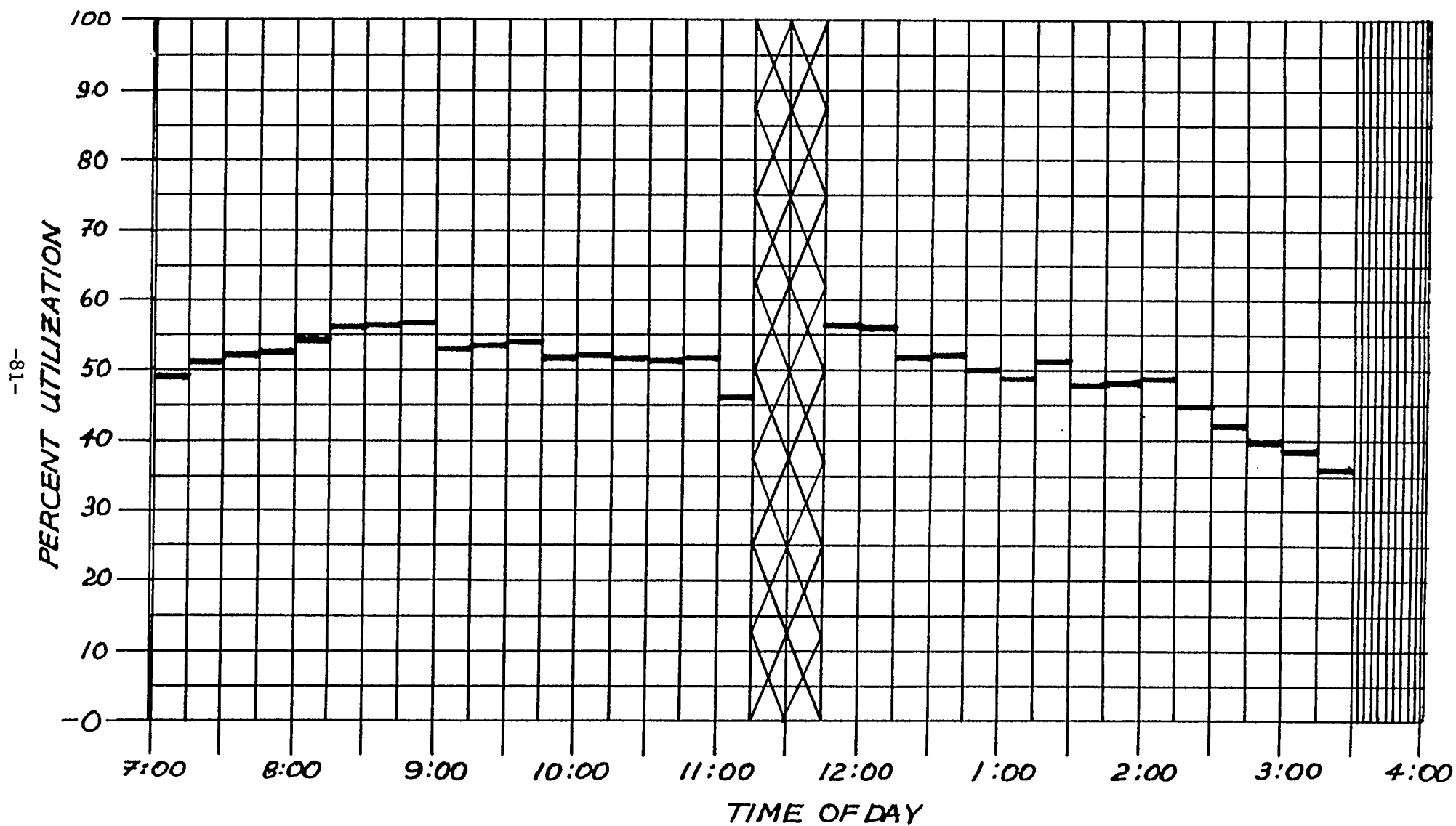


CHART B

UTILIZATION WITH RESPECT TO TIME OF DAY



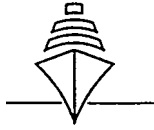


Forklift Assignment Area	FORKLIFTS			UTILIZATION	
	Present No.	Proposed No.	No. Reduced	Current	Projected
General Vicinity shops (3)	4	1	3	15.0	65.0
Mtl. Handling	5	2	3	38.0	67.0
Other Shops	11	11	-0-	50.0	50.0
Transportation	50	45	5	60.0	70.0
TOTALS	70	59	11	50.0	68.0
	Fleet reduced by 11 trucks.			Utilization increased to 68.0%	

The increased utilization looks very impressive in comparison to what it was. However, some people may believe it still is on the low side when compared with normal manufacturing operations.

With forklift utilization, you cannot expect to achieve 100% utilization. If it is achieved, the areas the forklifts service may suffer and their performance will go downhill due to the excess waiting on the forklifts. A general rule of thumb has been that 75% utilization of forklifts is the expected practical maximum. However, along with a study on forklift utilization you should study the areas the forklifts service. Don't improve in one area and handicap another without realizing it.

The Industrial Engineering group found a sales job on its hands also. They convinced the Transportation supervisor of their findings after they explained the work sampling method and taught the supervisor how to do some sampling on his own. The eleven forklifts and their operators will be eliminated through attrition.



CASE STUDY: PNEUMATICS DEPARTMENT

The Pneumatics Department of the Shoalwater Shipyard and Drydock Company is assigned the job of cleaning up after the welders so that the constructed or repaired steel units are ready for blasting and painting.

When welders strike an arc, the favorite way to do it is by "scratching" the electrode along the material next to the weld. This leaves a trail of weld beads that need to be removed from the plate surface.

Fitting aids are also a problem; clip, dogs, long-supports, and saddles are one-side welded on the plate to support the member before tacking. When these pieces are broken off by hammering on the side of the bracket opposite the weld, a residue of weld material remains. Also, pieces are welded for other reasons, especially supports for "come-along" hoists, porta-powers, etc.

The net result is that after the welders leave, there is a "fixed mess" and the pneumatics people have the job of cleaning it up.

Large weld residues are chipped off first and a variety of chisels are used in a pneumatic gun. Of course the operators rarely have the correct chisel so frequent trips are made to their tool bags, usually stashed somewhere else, to get the correct chisel. Also, frequent trips are made to the pedestal grinder (average distance 200 paces) to sharpen the chisels - usually one chisel at a time.

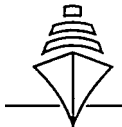
One foreman is assigned about twelve operators who usually work individually, spread out all over the yard. The foreman only has time to check his men every three or four hours.

Chipping is similar to operating a small jackhammer. It is noisy and few people like to do it. There are frequent complaints of hearing loss, yet it is a major problem to get the operators to wear ear protection. The operators are supposed to wear a face shield as well as safety glasses with side shields; they do this quite faithfully.

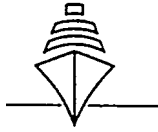
After chipping, the same operator grinds the metal plate to a smooth surface.

The chipping tool is taken back to the tool bag and in the words of the methods description: "Chipper asides tool, walks to tool bag, gets needed tool, and returns to job site. Aside tool and pick up hose lead. Kink hose by bending it double and grip with hand to crimp off air. Bleed air from system and loosen tool from hose. Aside tool and pick up needed tool. Fasten tool to hose and release hose. Carry tool to edge of panel and test run and blow oil out ensuring none gets on panel."

Grinding is done with a sanding disc or a grinding wheel. Wheels are purchased by apparently nonspecific instructions by the foreman, in rather large quantities, with orders going to the lowest bidder. There has been a rash of broken wheels with pieces flying around. Supervision at middle management level is concerned about the safety aspect (as is the safety specialist) but supervision is blaming the operator for incorrect grinding methods.



In the meanwhile, the work gets done although nobody is happy. The safety specialist listed the problem as a critical one and top management has ordered it solved -- at the same time improving the operation if possible. What would you do?

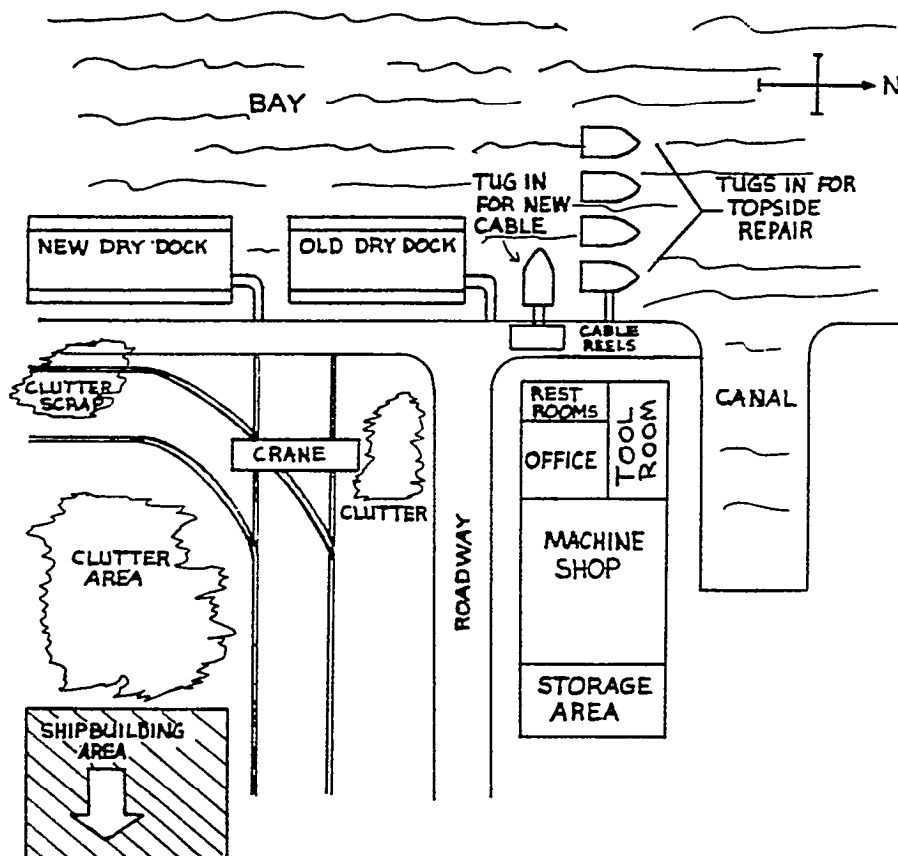


CASE STUDY: THE BOTTLENECK HARBOR SHIPYARD AND DRYDOCK COMPANY

The Bottleneck Harbor Shipyard and Drydock Company is a versatile facility that employs a full-time direct labor force of 140. The backbone of the company is a new floating drydock capable of hauling 235 ft. vessels up to 1,800 tons with a maximum beam of 46 ft. and maximum draft of 15 ft. It will also handle barges up to 270 ft. long. A second drydock is also used which has a slightly smaller capacity, but it is very old, requires a great deal of maintenance, and takes about three times as long to flood and refloat as the new drydock. For this reason, the longer term jobs are usually assigned to the old drydock. Since the short jobs require more workers, there are usually twice as many people working on the new drydock than the old one at any given time.

The company produces one or two small ships a year in the 120 foot category, but its main business is maintenance and repair work, mostly for ocean-going tug boats. Removing old towing cable and installing new cable is an important part of this service, and cable reels are handled on a special area north of the old drydock. The services of the yard are available to the general public as well as the maritime industry on a twenty-four hour, seven-days-a-week basis.

A sketch of the Shipyard and Drydock Company follows:





A work sampling study has been taken with the following results:

Working	36.8%
Idle	16.5%
Walk Empty	16.1%
Walk Loaded	15.4%
Persnol	5.7%
Truck or Lift	2.8%
Tool Room	6.1%
Other	.6%
Total	<u>100.0%</u>

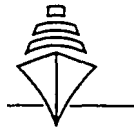
The Working and Idle categories are obvious as to their meaning. walk Empty implies that worker is walking to or from a destination but carrying nothing, whereas Walk Loaded implies that a worker is carrying welding rod, nuts, bolts, cutters, etc. Personal time is as the name implies - getting a drink, going to the rest room, smoking a cigarette, etc. The Truck or Lift category had been included to get an idea of equipment utilization. This category was recorded when a piece of equipment was observed at work as an observation was being made. The Tool Room category was used when a worker was observed in the tool room. There are actually two categories of items taken from the tool room, (1) high usage and expendable items such as nuts, bolts, welding rod, wire, marking chucks, etc., and (2) equipment such as chains, small winches, bolt cutters, torches, etc. Most of the tool room observations were of the item (1) nature, although both have been lumped together in the work sampling.

It takes an average of 200 paces to walk from the new drydock to the tool room and 75 paces from the old drydock to the tool room. Straight line walking is difficult due to the clutter and debris throughout the yard.

The company has a policy of providing emergency service on an "as needed" basis. When an emergency job comes up, labor has to be pulled away from regular jobs and put on the emergency job; the better customers have gotten into the habit of calling every job "an emergency."

Heavy loads are being lifted by two or three workers due to a shortage of hand trucks. A large overhead crane is very old and usually inoperative due to breakdown, a lack of replacement parts, etc. Three fork lift trucks are used as well as one portable crane, which is usually in the tug boat repair area.

Morale is low and the company has had two warnings from the Office of Safety and Health Administration (OSHA) for safety violations. Productivity is down and the company is presently in a no-profit situation.

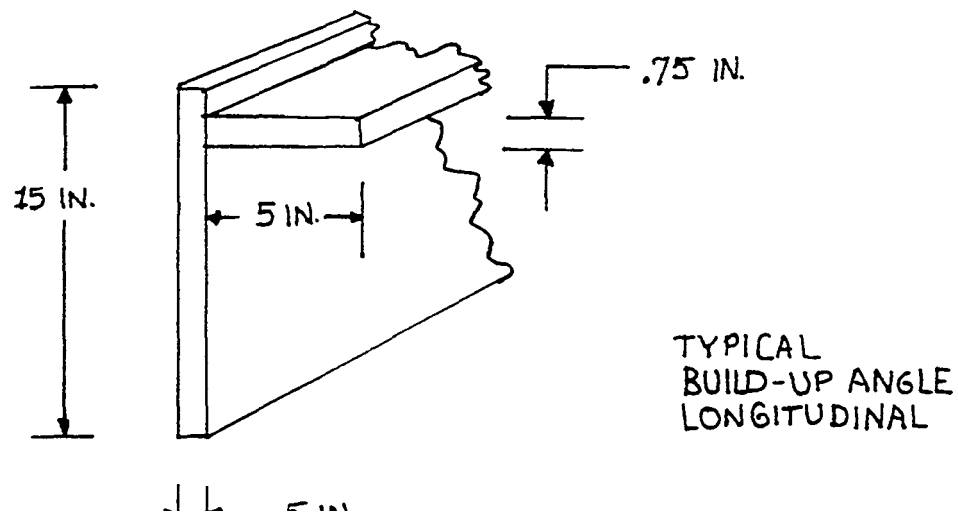


CASE STUDY: LONGITUDINAL FITTING AIDS

In shipbuilding, after the plates have been paroled and sometimes rolled, the next operation usually involves fitting and welding longitudinals. These are the long, shaped, steel members that form the initial "beefing up" of the steel shell. Similar members in a ship are called stiffeners or stringers.

No matter what they are called or shaped, they are unstable and fitting and tacking a "long" to a panel can be dangerous.

A typical built-up angle can be 40 feet long, weigh 1,500 pounds and have the dimensions shown here:



A typical method for attaching a long to a side shell begins with the layout man marking a molded line for that member (on the panel in the course of the layout process).

As the molded line shows where the edge or lower corner of the "long" goes on the panel, the layout man also marks which side the long lays on.

After this the fitter welds two or more pairs of steel clips to the panel, essentially tacking some holding aids on the panel to support the long in place when it is lowered by the bridge crane.

Taking care to make sure the long is initially supported, the fitters use wedges, saddles, and clips to position the long at the layout line and close any gaps between the long and the panel.

Encouraging the concept that there's always a better way (and keeping our eyes open at the other shipyards) we have come up with other ways to simplify the fitting of longs and other members.



Perhaps the most handy is the triangular fitting aid shown in one of the accompanying slides. Also, taking advantage of new bars issued to true up the platen, some gad gets have been devised to make fitting longs easier and quicker.

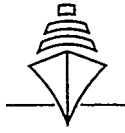
After all longs are fitted, the welders come in with their machines and completely weld the long to the panel. The frames are then placed and go through a similar procedure but with braces rather than fitting aids.

This section is not intended to describe to you how to fit longs. The objective is to use an operation that is very common and consequently very manpower-intensive as a Cost-avoidance example. As methods engineers we shouldn't fool around with 'onesies' and "twosies" but go after the big game.

After linking at the slides what ideas do you have to handle this problem?

Slide

- 1 Panel in place. Note mold line.
- 2 Wedge and dog used to fasten panel to platen.
- 3 Fitting aids to support longs; scrap pieces used also.
- 4 Longs in place before fitting.
- 5 Special clip to support longs; great improvement. Note a tout for two different sized built-up angles and lightening and hand holes.
- 6 Special fitting aids.
- 7 Strongback used for aligning two longs. Used to pull them into vertical alignment.
- 8 Strongback and special fixtures used to pull longs into horizontal alignment.
- 9 Same as previous slide; note wedge.
- 10 "Porta-powers" - What do you call them?
- 11 Bracing a frame with a "come-along." Note handy clip that fastens on to the long.
- 12 Bracing longs on a curved section. Not yet pulled into position.
- 13 Bracing is complete bulkhead unit into position. Tanker.
- 14 Bulkhead.
- 15 Close-up view of telescoping, adjustable brace. Permits fine adjustment.



AN IN INTRODUCTION TO SHIPYARD LAYOUT PRINCIPLES

The term "plant layout" can mean the actual rearrangement of manufacturing of industrial facilities and equipment, or it can mean only the planning involved to do so. The actual layout may be the complete installation of brand new facilities in a shipyard. It could also be the rearrangement of existing facilities in an existing yard, or the partial arrangement of machinery and/or equipment for specific instances or particular jobs.

The overall objective of shipyard layout is to provide the most economic productive operation with due consideration to safety and employee morale. The agents of production (men, materials, and machinery) along with their supporting functions must be arranged to conform to this objective.

Some specific objectives of shipyard layout can be listed as follows:

- The movement of materials must be reduced to a minimum.
- Safety and employee morale must be considered.
- The effective utilization of all space must be attained.
- Work must be kept flowing throughout the year.
- The arrangement must be flexible enough to allow for readjustment when necessary.

The three agents of production are men, materials, and machinery. The introduction of materials into a manufacturing operation depends a great deal a operation sequence. (For example, if an assembly requires a nut, a washer, and a bolt, it would be impractical, in most cases, to assemble the nut and bolt first, and add the washer later.) Based on this idea, it can readily be seen that the introduction of materials to a manufacturing operation depends on the placement of men and the location of machinery.

The three types of layout arrangements most common in industry are:

1. Plant Layout By Fixed Material Location

This layout is employed where it is not economical or practical to change the location of the product as it undergoes various steps of assembly or manufacture. For example, consider the assembly of an oil tanker in a shipyard, or a large electrical generator, weighing several tons. When products like these are produced, the tools, the men, the machinery, and all other necessary pieces of supporting equipment are brought to the machinery (example: platen area, building positions). The major component stays in one location while all of the necessary operations are performed on it in that location.



2. Plant Layout By Function or Process

This type of plant layout is in general use, especially where "job shop" or short manufacturing lot sizes are common. In a layout by function or process, all operations employing the same or similar types of processing are grouped together. For example, consider an electrical or electronic assembly where drilling is all performed in one area, soldering in another area, painting in another area, and assembly in still another area. All of the equipment, for example drills, are common to one physical location and the work is routed through that particular department in lots or batches. The material is brought to the man and machine (example: stationary burning machine).

3. Plant Layout By Product or Line

The layout by line production is probably better known as the "assembly line." Like the product that is assembled in a fixed material location, one type of product is produced in one general location. However, in line production, one operation is directly followed by another. Equipment and materials are arranged according to the sequence of operations and are used in that order regardless of function. The material and man are brought to the machine (example: panel line). Many familiar products are assembled in this reamer, including automobiles and household appliances.

Most shipyard layouts are a combination (or compromise) of the three types of layout arrangements. However, the majority of yard layouts utilize the fixed material location layout.

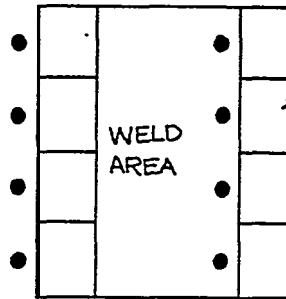
The purpose of this lesson is to acquaint you with various simplified plant layout techniques. This should enable you to recognize possible areas of layout improvement in your own department, shop area, or yard. Shop layout sketches in this section pertain to a fabrication shop with an end product of small parts used in ship erection. We can use this layout to determine the placement of workers, the flow of material,¹ and the utilization of machine space.

Determining the Areas of Worker Concentration

A quick method of finding the most "heavily populated" areas in a department or yard will help point the way to a better layout.

On Worksheet "A" you will find the general floor plan of a fabrication shop. Place a sheet of carbon paper behind the sketch and a blank sheet of paper behind the carbon paper. (A sheet of carbon paper is included in your student material).

The following list a the next page will tell you where the worker's stations are located. As you read the list, indicate the position of the worker on the layout by a dot. For example -- eight workers are located at the eight weld machines in this weld are, one worker to the left of each machine. you would indicate their position by placing eight dots as shown:



Worker Positions

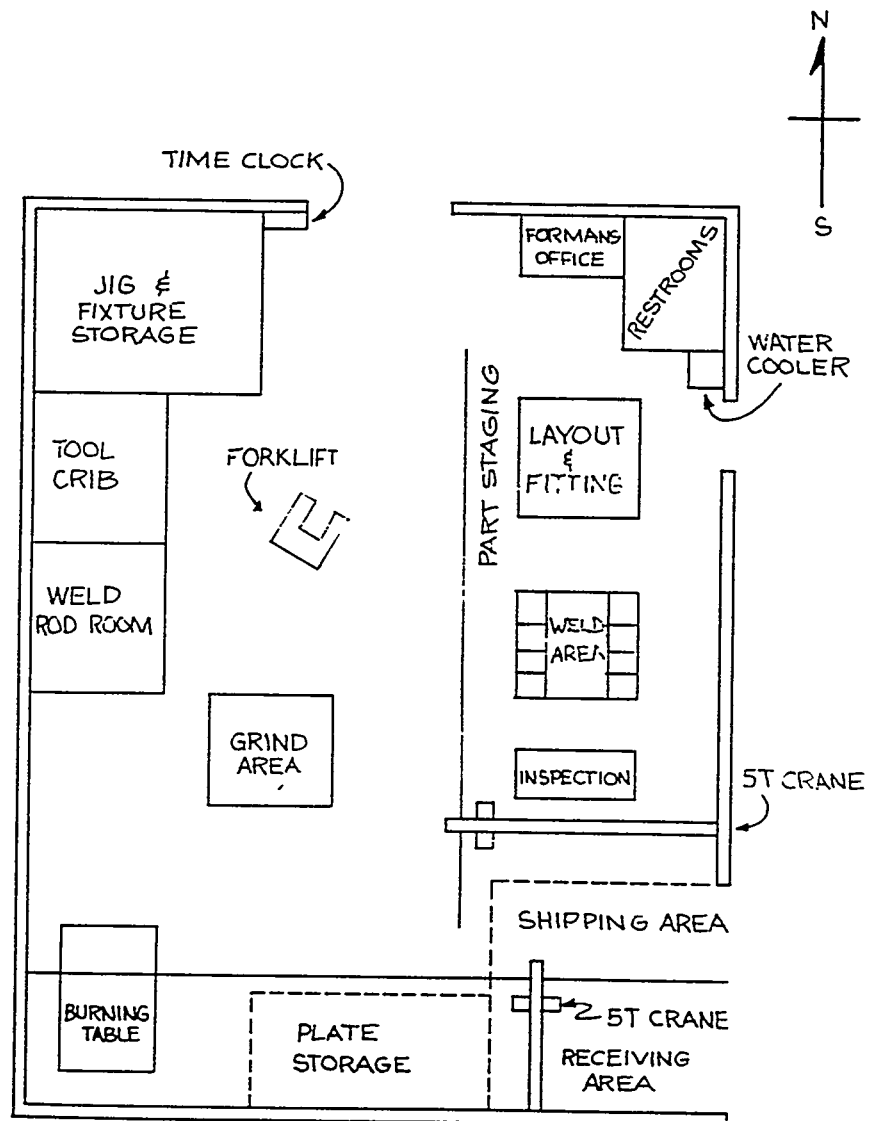
<u>Location</u>	<u>No. Workers</u>	<u>Placement</u>
Storage plate	2	Within area near center
Receiving area	1	Under 5T crane
Shipping area	4	Evenly spaced toward each corner
Eight weld machines	8	One worker to left of each machine
Grind area	2	At random
Foreman office	1	In center of office
Tool crib	2	Near center evenly spaced
Weld rod room	1	At random
Jig and fixture storage	1	At random
Forklift	1	Center of plant
Layout area	2	Two workers to the right (north) side of layout area
Fitting area	4	At random in fitting area
Inspection bench	2	One at north side of table, one at left side
Parts staging	2	At random in staging area
Burning table	1	Right side of table



When you have finished indicating the location of each worker, remove the carbon paper and examine the pattern of dots on the second sheet of paper. You should be able to determine the area of heaviest worker concentration quite easily. When you decide where worker concentration is the heaviest, draw a circle around that area, and turn to Works beet "A" Solution and compare your results with the results shown there.

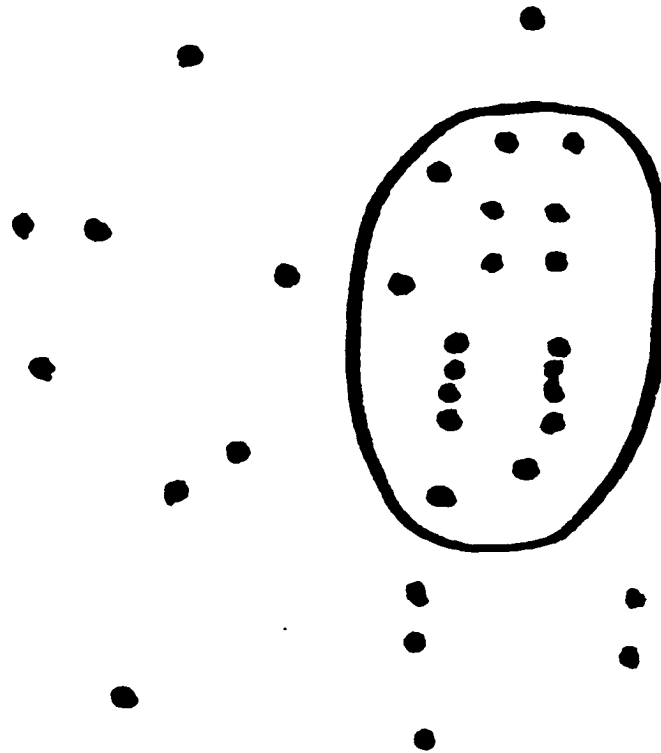


WORKSHEET "A"





Worksheet "A" Solution



We have determined the area of heaviest employee concentration to be in the fitting and weld area, as shown here.

The location of workers in a department or yard can have a direct influence on the location of facilities such as washroom, time clocks, personal lockers, water coolers, and so on. It is best to locate these close to areas of heavy employee concentration in order to cut down the time that workers spend walking to and from them.



Determining the Flow of Material

It is easier to determine where backtracking and excessive material travel is present if you can illustrate it visually on a sketch. Use Sketch No. 1 on the next page and record the path of the material flow by placing the letters shown at the correct place on the sketch. For example, the material is first delivered to the receiving area (shown as A) and moves to plate storage by overhead crane (shown as B). The material then moves through the following step:

- c. To burning table
- D. Parts staging for grinding area
- E. To grinding
- F. To holding area
- G. Transport by forklift to parts staging
- H. From parts staging to layout and fitting area by overhead crane
- I. From fitting to inspection by overhead crane
- J. From inspection to welding by overhead crane
- K. From welding to fitting by overhead crane
- L. From fitting to inspection by overhead crane
- M. From inspection to welding by overhead crane
- N. From welding to inspection by overhead crane
- O. From inspection to shipping by overhead crane
- P. From shipping to ship by forklift

Now, connect the letters from A to P to determine the flow of material.

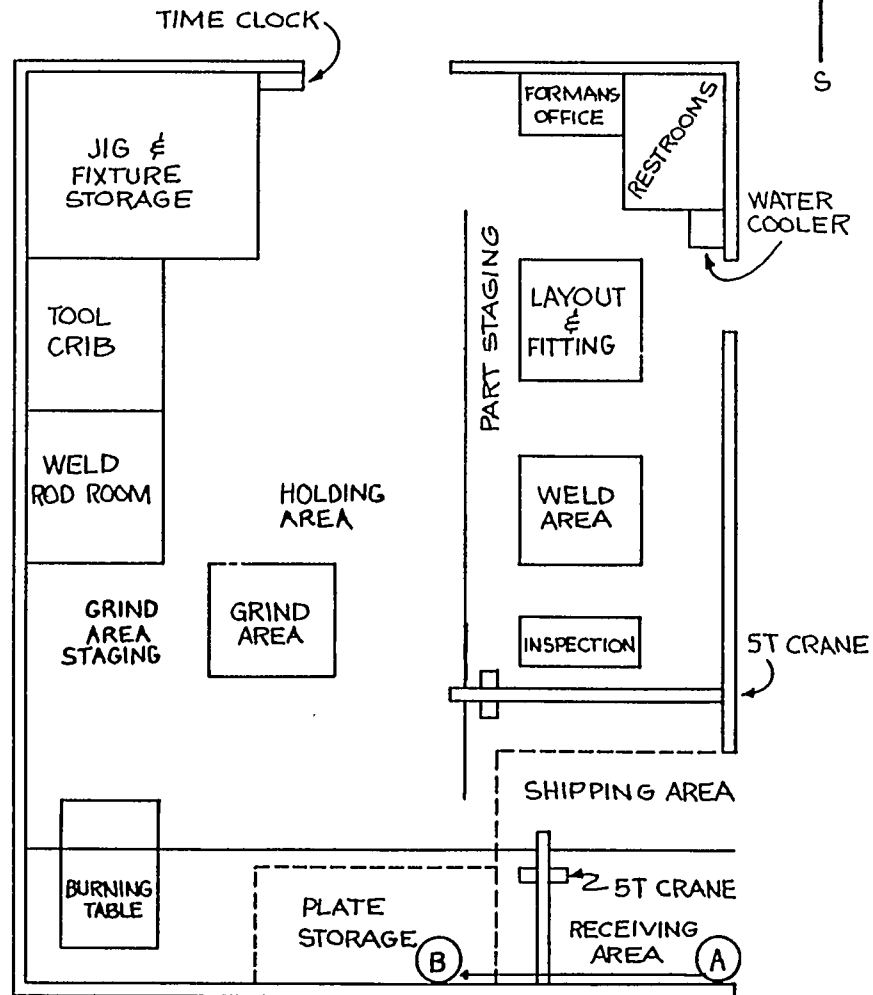
It is obvious that much backtracking occurs between the fitting, welding and inspection operations when the layout is arranged as shown in Sketch No. 1.

Sketch No. 2 shows a rearrangement of the weld area and the elimination of inspection benches. Draw in the same operation sequence from step G to O (omit inspection steps) using layout shown in Sketch No. 2.

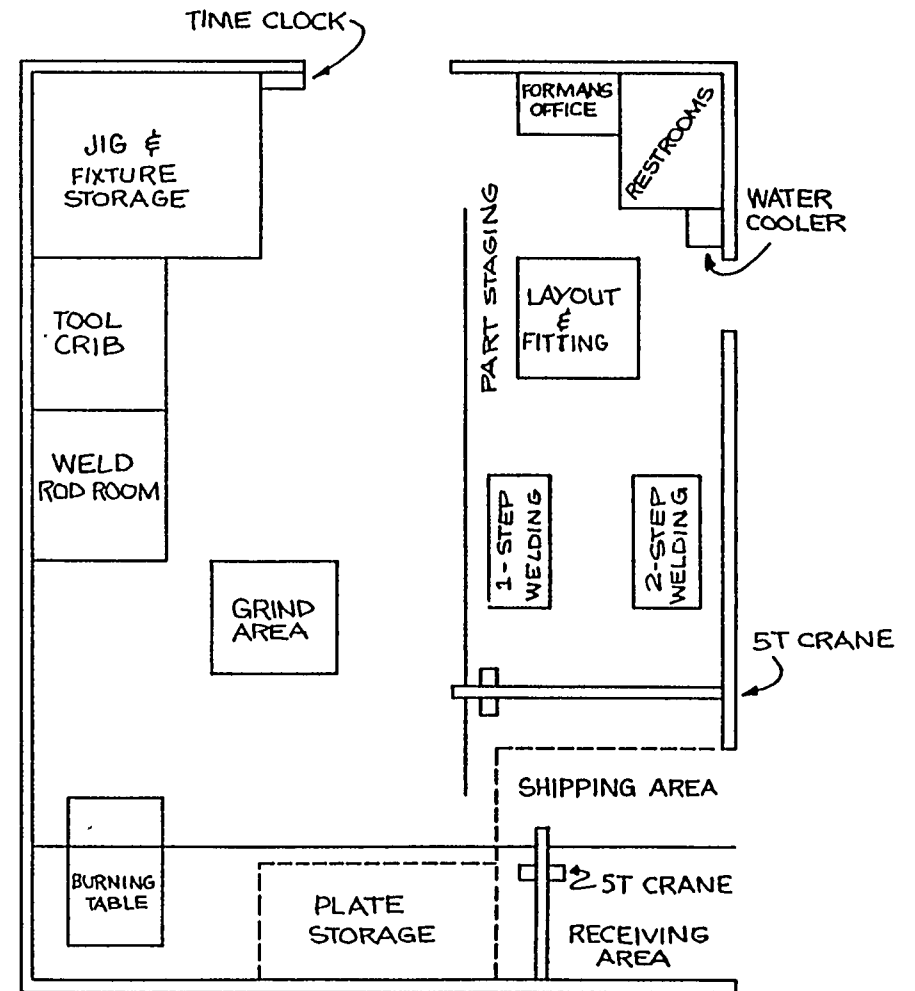
The tin-man inspection team has been moved from a stationary inspection position to a roving mode, inspecting parts as required. This will allow more room for actual production operations and reduce crane utilization which could be a major delay since there is only one in this area.

A comparison of the two sketches will show that backtracking and excessive material travel have been reduced by rearranging the weld area and elimination of inspection benches as shown in Sketch No. 2. Compare your layouts with the ones shown in the solution.

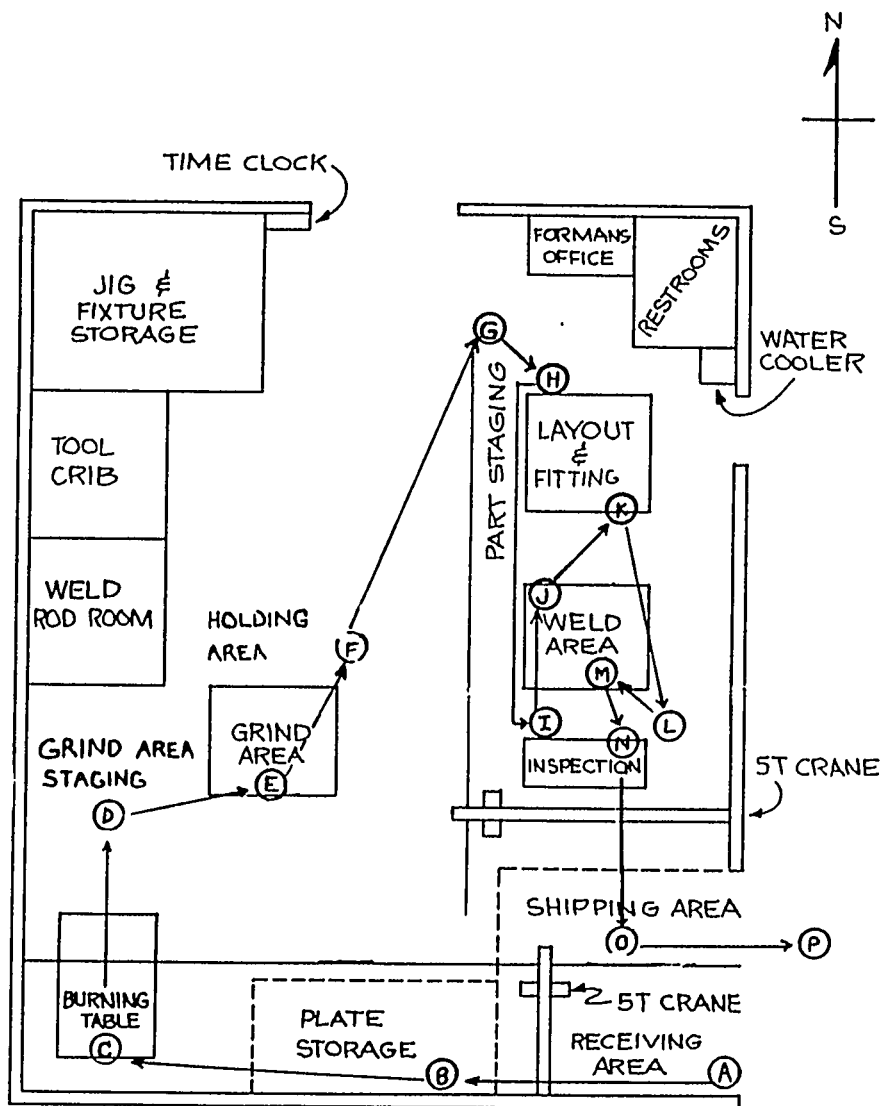
SKETCH No. 1



SKETCH No. 2

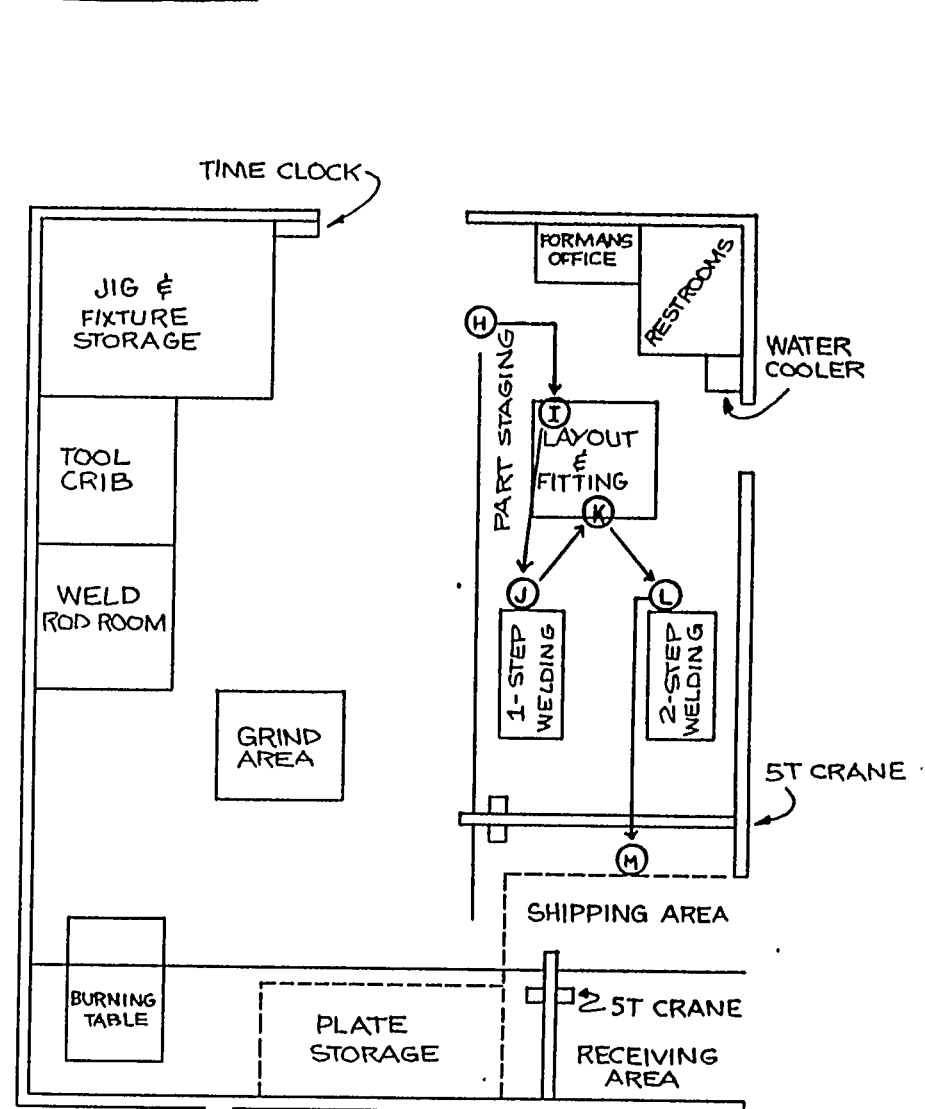


SKETCH No. 1



Note backtracking and excessive distance

SKETCH No. 2



Backtracking and distance reduced



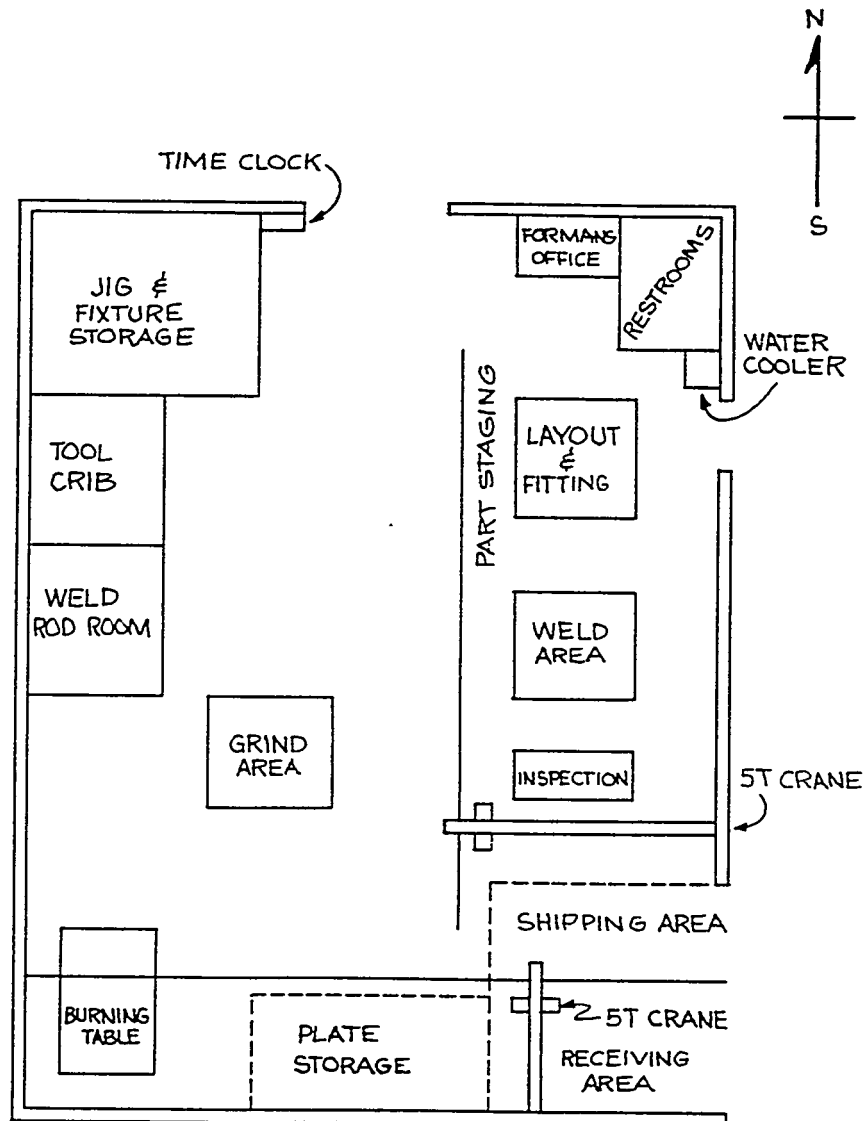
Determining the Utilization of Manufacturing Space

How can you determine the amount of manufacturing space there should be as compared to nonmanufacturing space? There is no "out and dry" answer to this question, but many plant layout authorities say that the "ideal" floor space ratio should be 30% nonmanufacturing to 70% manufacturing. These figures will vary widely, of course, depending on the particular industry and product. In shipbuilding this ratio actually reverses: 75% nonmanufacturing to 25% manufacturing.

There is a quick way to roughly determine how well you are using plant space. This is shown on the next page.

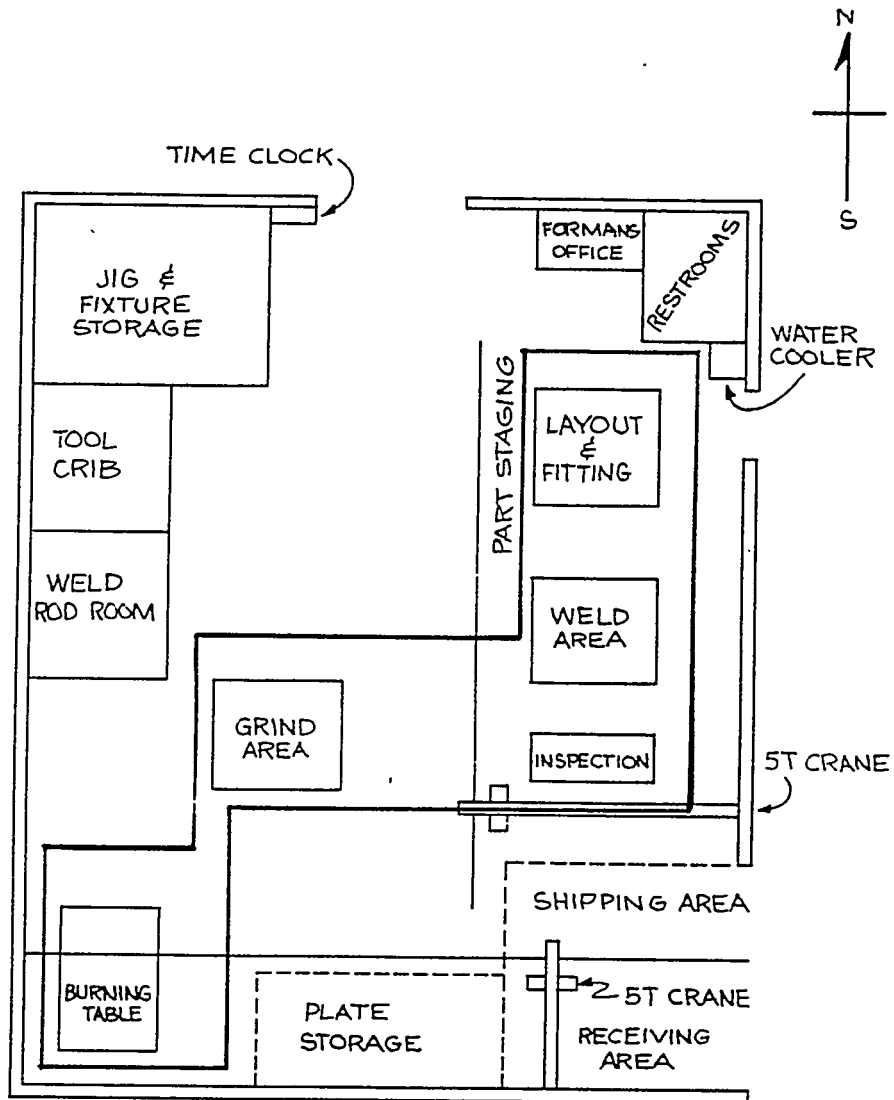


In the sketch below, encircle the area that is manufacturing space. When you complete this, check it against the example shown on the next page.





The manufacturing space encircled here represents 29% of the total floor space that produces the product which, in turn, is sold to produce dollars. A good layout will reduce the nonproductive areas to a minimum and provide more space for manufacturing.





Section VIII Selling the Improvement and Maintaining It

Selling the Concept 101

Maintaining the New Method 104





SELLING THE CONCEPT

Overcoming Resistance

Resistance to change is a major impediment to methods improvement activities in most organizations and shipyards are no exception. As irrational as such resistance may seem at times, it does serve the purpose of testing new ideas so that they will not be accepted and implemented prematurely. Once you understand the individual and organizational obstacles that inhibit change, you will be able to develop your creativity more fully and "sell" your ideas more successfully.

Even after you've worked out a tough problem you may find that no one is interested. Sometimes this is due to lack of confidence in merits of the idea, but most often it is due to your neglecting to get others involved in your solutions.

Methods improvement implementation requires cooperative effort. But many people get so ego-involved with their ideas that suggestions for modification are automatically opposed as unnecessary tampering. As a result, they fail to elicit the participation and cooperation of associates during the development and implementation stages.

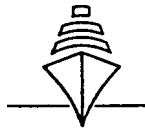
Suggestions for improvement should be heartily welcomed. When others take an interest in your idea, they become personally involved; your idea becomes "our idea." If you are generous in sharing the idea with others, everyone will be a winner and you will be remembered as the one who came up with the original concept in the first place. On the other hand, if you cling to the purity of your idea too strongly, others will not come to your aid when you run into obstacles. Insistence on receiving all the credit for an idea is not only unrealistic in most organizations; it is the quickest route to resentment.

Threat to Authority or Position

Some people react negatively to new ideas because the ideas are not their own. Managers and supervisors are especially prone to play down the value of new ideas because they feel that their power and status are threatened if their subordinates or associates suggest them. They believe that if changes are necessary, they should be the ones to think of them.

Change is also frequently fought because it makes someone's job insecure or tumbles an expert from his pinnacle of recognition. For example, a technical innovation may introduce a new approach to a particular job. A person who for years has followed a proven practice with great skill and confidence may suddenly find himself to be a novice who is feeling his way down the painful path of learning a new skill. He may feel that the change threatens his earnings or his chances for advancement or recognition.

Perhaps the most prevalent reason for new ideas being viewed as a threat to existing authority or position is when the ideas that originate in one department directly affect people in another department. In the typical organization,



each person's responsibility is carefully defined and looked on as his own special preserve. When somebody comes up with an idea that concerns another person's area of responsibility or expertise, the usual reaction is defensiveness or hostility. The affected person feels that someone is trying to trespass into his area of authority and responsibility.

This artificial but very real barrier to change not only kills a lot of valuable ideas; it also prevents the free flow of information and communication that should exist between departments.

Gaining Management Acceptance

A lot of people can't sell their ideas to management. They may simply be afraid of rejection or, more likely, be reluctant to undertake the work involved in preparing an effective presentation.

Often the person you're submitting your idea to won't even realize that there is a need for it. You may have to begin at the beginning and go through the whole reasoning process that you followed in creating your idea.

presenting a new idea is in many ways one of the most crucial aspects of the methods improvement process. Here are some ways to improve your chance of success:

1. Presenting to a group? Try to sell it before the meeting to one or more members. They'll appreciate your advance confidence and, possibly, rally to your side if the going gets rough during the presentation.
2. Give background. Before actually presenting the idea, give a short history of the problem, which led you to investigate the area and how you proceeded to solve the problem and created the new idea.
3. Show them you've thought it out. Demonstrate by your conversation that this idea isn't the first one you've dreamed up. You've thought the problem out and made various approaches and refinements until you're satisfied that you have something worthwhile. The person who goes off half-cocked all the time may be fine to stimulate others around him in an idea session, but when you're ready to "sell" an idea, you must be prepared to prove that you've thought it through.
4. Go slowly. The presentation of new material should be delivered no faster than it can be understood and absorbed. Clear language is absolutely necessary. Take special care to eliminate trade jargon unless your audience is at home with such language.
5. Emphasize the money angle, where appropriate. When selling an idea to top management, remember that a strong dollars and cents case must be made. The possible savings potential or profit potential should be demonstrated and the presentation should include plenty of business benefits, not just an explanation of how it works.



6. Don't knock the status quo. Your audience may have been intimately involved in getting things running the way they do now, so don't be hypercritical of "things-as-they-are". Instead, talk about the better times ahead--if your idea is accepted.
7. Sum up. At the end of your presentation, sum up the outstanding points, the anticipated advantages of the idea, the need that exists or can be created for the idea and why you think the idea should be adopted.
8. Put it in writing. Not everyone is constitutionally capable of following an oral presentation, so stack the odds in your favor by leaving copies of a clear, well written report with your listeners that will give them a chance to study it later.

Implementation

The groundwork for implementing a methods improvement project or another project actually starts with selecting the work to be studied. What you do and how you do it from that point to the time you are going to make the change will determine the success of implementation. Have you:

- Involved everyone concerned
- Listened to their ideas
- Taken the time to completely understand the current method
- Conducted a thorough analysis
- Sold the idea and answered all questions?

Then you will have all the detail and support required. If not, be ready for a rough implementation period.

Training

In most cases when introducing a new method, the worker will require retraining. In the training the most important thing will be to develop a habit of doing the job the correct way. Habit is a valuable aid in increased productivity as it reduces the need for conscious thought. Good habits can be formed just as easily as bad ones.

Beginners can be taught to follow a numbered sequence illustrated on a chart or they may be taught on the machine itself. Either way, they must be made to understand the reason for every movement.

As part of the process of installation, it is essential to keep in close touch with the job, once it has been started, to ensure that the employee is developing speed and skill and that there are no unforeseen snags. This activity is often known as "nursing" the new method.

Only when you are satisfied that the productivity of the job is at the level of your expectations and the operator has settled down to it, can it be left for a time.



MAINTAINING THE NEW METHOD

It is important that, when a method is installed, it should be maintained in its specified form, and that workers should not be allowed to slip back into old methods, or introduce elements not allowed for, unless there is very good reason for doing so.

To be maintained, a method must first be very clearly defined and specified. Tools, layout, and elements of movement must be specified beyond any risk of misinterpretation. The extent to which it is necessary to go into minute details will be determined by the job itself.

Action by the implementor is necessary to maintain the application of the new method because, human nature being what it is, workers and foreman will tend to allow a drift away from the method laid down, if there is no check. If it is found that an improvement can be made in the method (and there are very few methods which cannot be improved in time, often by the operator himself), this should be officially incorporated and a new specification drawn up. As noted before, one of the most *universally* used techniques to ensure adherence to approved methods is by use of a Labor Standards Reporting System.



Supplemental Materials

Paper: "The Rocky Road of Installing a Work Measurement System"

Productivity Brochure

SP-8 Publications

Note Paper

Carbon with Sheet for Exercise



THE ROCKY ROAD OF INSTALLING A WORK MEASUREMENT SYSTEM

William S. Oakes

National Steel and Shipbuilding Company

ABSTRACT

The author examines the relationship between the uses of a work measurement system, the technique used, and the problems of installation. A number of suggestions are made to insure a successful system.

WHY HAVE A WORK MEASUREMENT SYSTEM?

A work measurement system does not exist for itself alone. Work measurement is usually a method of determining, technically, how much time a task should take. These standard times may range from the various direct labor jobs in a factory, to office work in a bank, to the professional man-years of a major engineering project.

Besides the level of standard time, it is important to determine the uses of the system you are thinking about because the two -- the use of the system and the work measurement techniques, relate to each other in an important way.

For example, the following page lists some of the preliminary considerations that you will make as you develop the relationship between the technique and activity of work measurement.

I remember my first simple introduction to work measurement systems from my boyhood.

In my father's sheet metal and plumbing shop was a small notebook marked, "COST BOOK". Here were listed the various materials, fittings, hourly rates and representative jobs, standard data so to speak, and their estimated labor content. His method of work measurement was similar to some of what we do today. A job was broken down into an appropriate number of small pieces, the material costed, the labor hours estimated, and the results totaled. He also used learning curves and self-logging.

The Oakes family did quite well. Because the cost estimates tended to be "centered" there were not too many disasters from too low estimates, and we did not lose too many important jobs because they were quoted too high.

WORK MEASUREMENT TECHNIQUES

1. Educated Guess. Probably the most common form.
2. Historical Analysis. Requires good records and retrieval. Locking in poor methods is a hazard.
3. Work Sampling. Good for a first look or comparing two operations.
4. Self-Logging. Asks the worker to record the time it takes to perform various tasks.
5. Time Study. Use a stopwatch.
6. Standard Data. Uses curves, nomographs, charts, or milestone sheets to present data in useable form. Usually relies on PTS.
7. Predetermined Time Systems (PTS). Various levels of MTM, MOST, MEK or UAS, Work Factor, etc. are used to measure the work to be performed -- not the person who performs it.

WORK MEASUREMENT ACTIVITIES

(The work measurement system is only part of these activities).

1. Is essential in providing information for a productivity improvement program to maximize the generation of profits.
2. Forms a basis for manpower cost estimates.
3. Provides an incentive to fix an inadequate management information system.
4. Enables job enlargement and enrichment by facilitating the design of challenging work stations or assignments.
5. Provides information for shop loading and work schedules.
6. Helps determine staffing levels.
7. Points out equipment needs and justification.
8. Promotes methods analysis and improvements in worker effectiveness.
9. Determines labor performance through using the ratio of measured work to actual work.
10. Improves worker morale. Employees like the idea that they all have a balanced, fair, workload -- and know where they stand.
11. Helps build and back up accurate standard data elements.
12. Can help predict the effect of new business.
13. Encourages other improvement projects unrelated to work measurement.
14. Assists in implementing a MIL-STD 1567 program.
15. "Balances" a production line so each station or each group has a similar work load.
16. Determines the probable labor cost of manufacturing a new product.
17. Many workers prefer to be judged by objective standards rather than the subjective opinion of their supervisors.
18. Helps establish what is a fair day's work.

COMPETITIVE COSTS!

19. A good work measurement system is essential for incentive or measured day-work plans.

20. Quality is often improved because of the connection between good work design and "building the quality in".

And you could add to this list with little effort.

It is one of the mysteries of the time why work measurement is not used more!

The actual reasons for having a work measurement system are complex. Ralph Sims [5] describes it very well with the concept of the "perceived need". Because at first the IE is probably in the position of initiating or selling the work measurement system, which probably is part of another system (i.e. productivity improvement), he faces a "sales situation". Quoting Mr. Sims:

"There must be a perceived need for a solution, acceptance of the expertise and authority of the professional, and a self-serving willingness on the part of management to accept the solution and implement it for the benefit of the company".

"The right solution must be presented at the right time, and funding must be available to meet a perceived need within an acceptable (corporate) policy framework".

Which brings us to the first roadblock:

ROCKY ROADBLOCK No. 1

Your work measurement system must fill a perceived need (which you may have helped articulate), be part of another useful activity, and be accepted by management.

Remember the list of uses, including your own additions. These are the qualities that you will be selling, not the work measurement system.

By now you will begin to see that there is no "golden chariot" that will take you to the promised land. Each work measurement system has to be custom designed, and classic engineering problem-solving techniques may suggest a way to do it.

A PROBLEM-SOLVING APPROACH

1. Define the problem situation.
2. Gather facts.
3. Determine what is needed.
4. Design a solution to meet these needs:
 - a. An overall system.
 - b. A detailed design. (May follow step 5).
5. Management review and go-ahead.
6. Implementation.
7. Maintenance of the system; correction if required.

DEFINE THE PROBLEM SITUATION

Using the concept of perceived need you will begin to define the proposed system. And at this time the need to involve the people affected becomes almost critical. As Professors New and Singer put it[1], "As a result of early involvement in the change process, employees may feel a sense of 'ownership' of the change that will motivate them to carry it out". And to help you define the problem too, we might add.

The kind of custom-designed system we are talking about will require the ideas and support of all those who will be affected.

This is not the place for a lone wolf. You are going to need people to volunteer to work for the new system with enthusiasm, people who will be vitally interested in its success, and who will be eager to invest time and effort. The involvement aspect will take all the talent you have, but it must be done.

So here is the second principle:

ROCKY ROAD SMOOTHING No.2

Involve all people who are affected or who can help.

This is enough of problem definition and team development. It is the most important step, however.

GATHER FACTS

We will not spend much time on this aspect, but it is obvious that you will have to study the product makeup, do statistical work and develop a data base of factual information.

You just cannot take an opinion survey. You need facts, with reliable statistical information taken in enough quantity to give proper confidence that you know what is going on, and where, and with hard numbers. The facts you gather will be guided by your definition of the project. We will need factual data for the next step.

DETERMINE WHAT IS NEEDED

When we discussed the suggested procedure a few minutes ago we talked about the perceived need, the definition and the fact-gathering situation. We are zeroing in on our opportunity. For this phase a checklist might be handy:

1. What are the outputs of the work measurement system?
2. Who, or what groups, will use your system?
3. Will you or the IE group be doing the application, or someone else? (Here you will have to think about the level of the technique you will use).
4. Where is the best place to start? Most authorities suggest a small place with easy to achieve results. But you know your situation, and opportunity.
5. How many industrial engineers and other personnel will be needed? What talent level will be required?
6. What goals do you have? This relates back to the users of your system, but change will probably be part of all of this.
7. What percent accuracy do you have to have? What confidence level? Certainly you do not want to require any higher level than you need, considering the balancing time available.
8. Are CAD/CAM computer systems in place? Are they part of the system you will be working with?

Try the psychological route in getting information but do not decide on the basis of how in the workers position. Find out what will work.

Mitchell Fein, who is also on the program, has written a number of excellent articles including one on reliability, precision and accuracy [3].

ROCKY ROAD HAZARD No. 3

Select the correct work measurement technique consistent with your requirements.

9. Define the desired end result of your system. Write it down. List.

10. If the goal is to overcome an existing problem, have you looked at the causes of the problem? Sometimes things are not what they seem. For example, no amount of work measurement will overcome an ergonomic problem.

ROCKY ROAD PREPARATION No. 4

Have a list of the main activities your work measurement system will be used for.

DESIGN A WORK MEASUREMENT SYSTEM

Perhaps specify is a better word than design, but by now you are involving more people and finding out what they will need and how they will use your system. More checklist:

1. Does the level of work measurement you are proposing (MTM-1, MOST, MTM-3, etc.) match your use of the system?
2. Does your data plan, the final result of your design, match what is needed?
3. Will your design sell itself?
4. What needs to be delivered at the end of the implementation phase?
5. Is your work measurement design understandable to the people who will use it? Here is another good place to get involvement as you play over the outputs (to meet your users' needs) with your "customers".
6. Have you played over your design proposal with senior management?

7. Have you considered a system such as "Improshare", Mitchell Fein's gain-sharing plan?

8. If available, have you considered a Quality Circle, or Quality of Working Life, problem-solving team to help contribute to the design requirements?

Time for another caveat: The Gray-Judson Corporation, a Boston-based management consulting firm [6], recently listed the result of a survey to determine why productivity improvement efforts fail. They found that piecemeal or uncoordinated approach to deal with the problem, poor coordination among departments, or excessive department autonomy were to blame for the failures.

All of these causes of failure, plus others you might list, point to poor design.

ROCKY ROAD CAVEAT No. 5

You just have to have an excellent design for your system, with outputs that are needed and will be used.

The design you work out, in conjunction with your "design team", will probably take the form of first working out an overall design. Then, after verification of its correctness, you will work out the details. There is no use working on details first. Certainly do not wind up having a solution looking for the problem, or a cure looking for the disease.

MANAGEMENT REVIEW AND GO AHEAD

At this point a management review and financial Commitment is in order. This is a good place to sell your team's proposals and develop management interest in your productivity-improving system. Emphasizing the ROI (return on investment) is a good way to generate interest.

Management is important. In a short reference [4] it is pointed out that a Brigham Young University survey "discovered that organizations with the worst labor problems had the poorest management. These companies failed to set clear productivity expectations, establish individual responsibility, provide worker feedback through appraisals, or encourage employees to develop their skills".

IMPLEMENTATION

With a little luck the implementation phase should go well. A good project definition and design will go a long way toward putting your team on the right track.

As we go implementing our design we have to keep in mind that the measured system is subservient to, not the focus of, the industrial engineering effort. Work measurement is integrated into the productivity-improvement activity.

Here are a few items for your implementation check list:

1. Have you developed an implementation master schedule?
2. Are you developing "psychological ownership" of some of the activities on the part of those affected?
3. Are you aware of the change resistors and some techniques to cope with them? (See 1). Tradition, inertia, and newness are problems. Try to move your project at the right speed so people can get used to change.
4. Are you setting up the implementation so that "insiders" (the people affected) will be doing the work rather than the outsiders (staff IEs)?
5. Are you bringing the goals of the people involved into convergence with those of the organization?
6. As problems develop, do you show people possible ways to solve the problem rather than doing it yourself?
7. Have you considered a physical move to the area of the operation you will be working with?

Professors New and Singer [1] presented some excellent ideas on how to involve people and overcome resistance to change. One quotation from their excellent article: "As a result of early involvement in the change process, employees may feel a sense of 'ownership' of the change that motivate them to carry it out"

Professor Odiorne, in a review of his new book [2], has a lot to say about the psychological aspects of change and implementation. Here is one quotation: "To initiate action, present the change as a new vision, something noble. You can stamp out something evil...or prove to people that they are better than they think...or stress the high moral qualities of the proposed action".

MAINTENANCE OF THE SYSTEM

This is part of the system design. Like all systems, maintenance and attention are required or degradation will take place.

Hal Lindemann is giving a program on the maintenance of work measurement systems.

Another truism:

ROCKY ROAD AVOIDANCE No. 6

Watch out for driving into a trap of being event-driven rather than system-driven. A good plan responds to what needs to be done, not the latest fire.

LAST THOUGHTS

We industrial engineers have a unique opportunity to help achieve some of society's ancient goals -- productivity, an increased standard of living, dignity, quality of life. We are in a position to correct the errors of the past and contribute to a better society.

ROCKY ROAD SIGN No. 7

Now that we've got where we're going, where's the next project?

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BIOGRAPHICAL SKETCH

William S. Oakes, P.E., is a Senior Industrial Engineer with National Steel and Shipbuilding Company. He is currently involved with industrial engineering applications to the shipbuilding industry in work sponsored by the National Shipbuilding Research Program. Mr. Oakes received a BSEE from the University of Oklahoma, and is experienced in MTS, MTM-1, and MOST predetermined time systems. A senior member of AIIE and SME, he is also a registered Professional engineer in California.

PRODUCTIVITY TODAY

**What Works and Doesn't Work
in the Quest For Productivity Improvement
as Judged by
the "Productivity Engineers" Themselves**

**A Summary of the Fourth Annual Productivity Survey
Conducted by the Institute of Industrial Engineers**

AN INSTITUTE EFFORT TO SPREAD THE WORD



INSTITUTE OF INDUSTRIAL ENGINEERS

American Institute of Industrial Engineers

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PRODUCTIVITY AND QUALITY WORK TOGETHER

Productivity and quality concern all of us. In fact, "productivity and Quality Work Together." Our 1985 campaign theme is targeted toward making citizens more aware of how productivity and quality affect them individually and collectively as a nation.

The Institute of Industrial Engineers conducts an annual survey to inform you and others in business, industry and government about productivity concepts. It is based on the responses of industrial engineers who implement productivity improvement programs and techniques on a daily basis.

This year, the Institute also is pleased to join hands with the Broadcasting Industry Council to Improve American Productivity, an organization also dedicated to spreading the word about this subject to as many citizens as possible.

Productivity and quality improvement are universal concerns. No synopsis can encompass the full scope of these far reaching topics. This summary report is but an overview of opinions and improvement methods in use today. We welcome your comments and inquiries on specific productivity examples.

Sincerely,

David L. Belden, Ph.D., P.E.
Executive Director

PRODUCTIVITY POLL EMPHASIZES MANAGEMENT UNDERSTANDING, EMPLOYEE INVOLVEMENT

As men and women whose training and experience are specifically aimed at productivity improvement, industrial engineers are well positioned to answer questions about productivity today.

Hundreds of these professionals took time to reflect on the status of productivity in America, candidly expressing their opinions about it in past, present and future tense.

Their views on what efforts toward productivity improvement will and won't work collectively show there's no single solution to any productivity problem, nor do these IEs reveal or claim to have any magic formula which can guarantee results. But this cross-section of information from a broad front of enterprises should be valuable as guidelines for management in industry, business and government.

And speaking of management, those running large and small organizations alike should take serious note of how they're looking at productivity. IEs put "management failing to understand how productivity can be

improved" at the top of the list of major obstacles to productivity improvement.

What about locations where management does comprehend the problem? Which general improvement areas can be expected to bring effective results? IEs believe capital investment for new or automated machinery remains the frontrunner, but this year's survey placed "formal employee involvement in productivity improvement planning and evaluation" in a strong runnerup position.

The role of management, employees and their application of skills as evaluated in this report seem to underline the re-emergence of human resources as the dominant factor in **productivity**

improvement, overshadowing even the amazing advances of society's working tools being automated by the advent of computerization.

As the decade of the Eighties reaches midpoint, integrating people and technology has become the critical move in the never-ending quest for improved productivity.

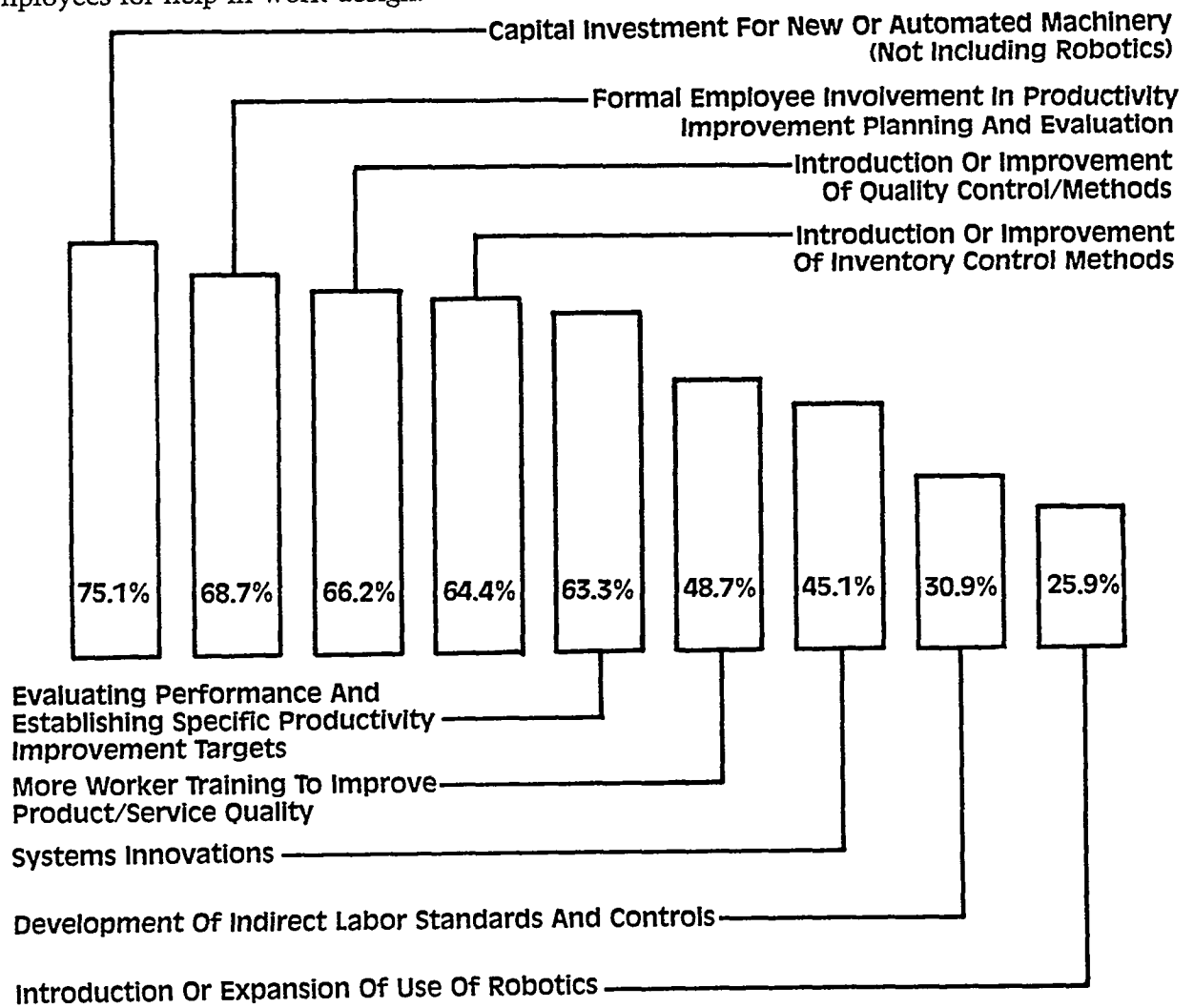


MOST SAY PRODUCTIVITY WORKS BEST WITH CAPITAL, COOPERATIVE SPIRIT

Many responsible for management decisions have for many years called capital investment the principal key to greater productivity, saying outdated equipment and facilities simply are too great a handicap for efficient output. Industrial engineers don't disagree with this attitude; in fact, three out of four responding to the 1984 survey say their locations have made capital investments in the past five years. Moreover, nearly 86 percent of those stating such capital investments had been made also said the investment resulted in a high degree of effectiveness.

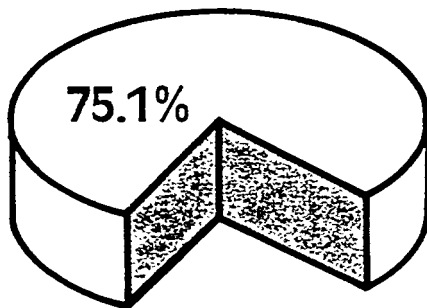
But money alone isn't the only answer.

Running a close second in types of activities named by the productivity experts was formal employee involvement in productivity improvement planning and evaluation. This includes such programs as quality circles and suggestion programs – activities giving employees a means to contribute their ideas and energies. Are such programs successful? More than half (63.1%) said the program was effective, supporting the theory that productivity thrives best where management looks to employees for help in work design.



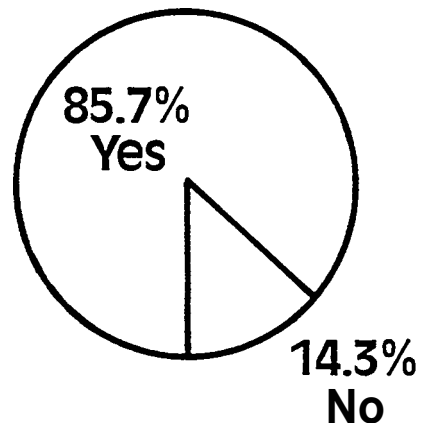
Q: Which productivity improvement activities have been undertaken at your facility in the past five Years? If undertaken, state whether effective.

CAPITAL INVESTMENT FOR NEW OR AUTOMATED MACHINERY (NOT INCLUDING ROBOTICS)

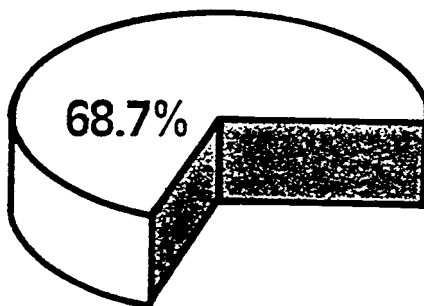


Base: 718

Effective?

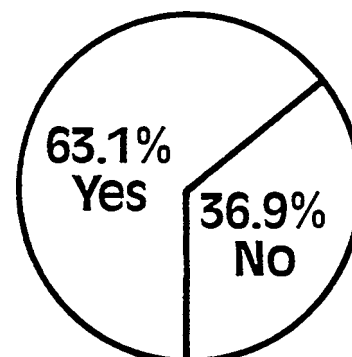


FORMAL EMPLOYEE INVOLVEMENT IN PRODUCTIVITY IMPROVEMENT PLANNING AND EVALUATION



Base: 719

Effective?

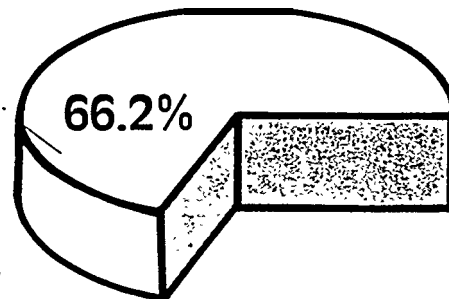


CONTROLS, TARGETS ALSO CITED

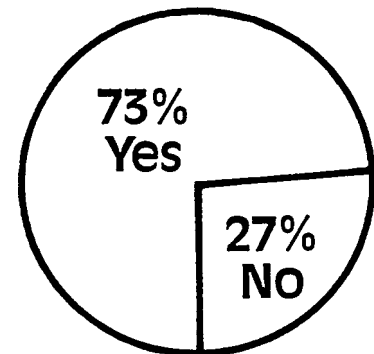
Introduction or improvement of quality control/methods ranked third in popularity among productivity improvement activities in facilities where interviewed IEs worked, followed closely by inventory control methods. And in both cases, most said these activities were effective (73% and 70.8% respectively). Next in order of popularity were specific programs to evaluate performance and establish productivity improvement targets. Here again, a strong majority (66.7%) said such programs were effective.

INTRODUCTION OR IMPROVEMENT OF QUALITY CONTROL/METHODS

Base: 707

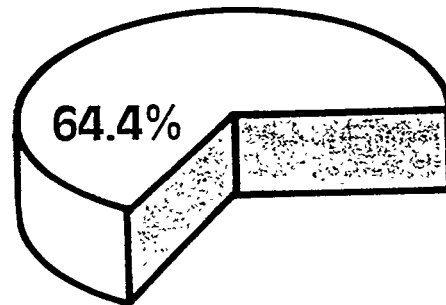


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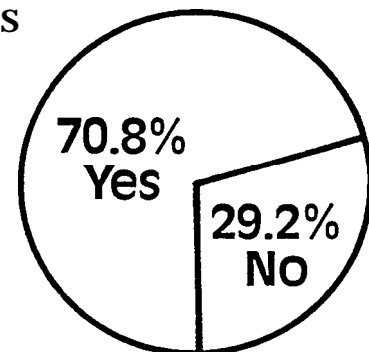


INTRODUCTION OR IMPROVEMENT OF INVENTORY CONTROL METHODS

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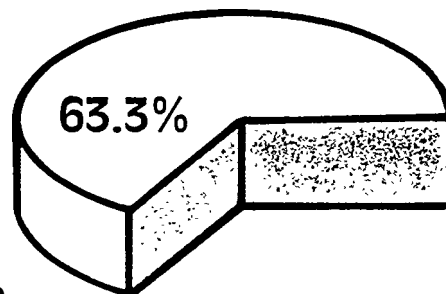


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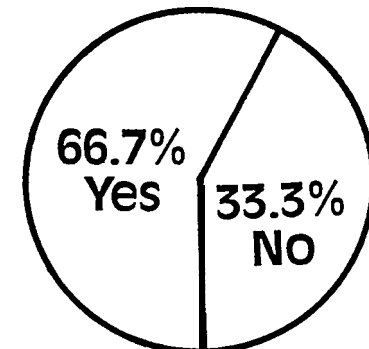


EVALUATING PERFORMANCE AND ESTABLISHING SPECIFIC PRODUCTIVITY IMPROVEMENT TARGETS

Base: 719



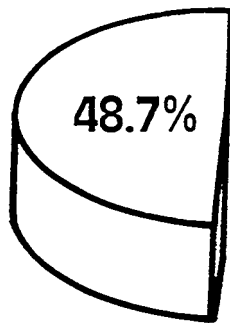
Effective?



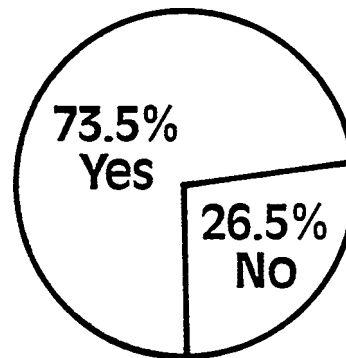
EMPLOYEE TRAINING LEADS NEXT THREE

Among productivity improvement ideas undertaken at less than half of facilities where surveyed IEs work but which still had considerable support include more worker training to improve quality (48.7%) systems innovation – such as integrated factories, advanced material handling techniques and computerized manufacturing methods (45.1%), and development of indirect labor standards and controls (30.9%). Of these, more said worker training was effective.

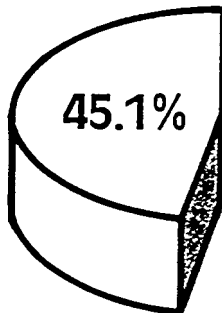
MORE WORKER TRAINING TO IMPROVE Effective? PRODUCT/SERVICE QUALITY



Base: 705

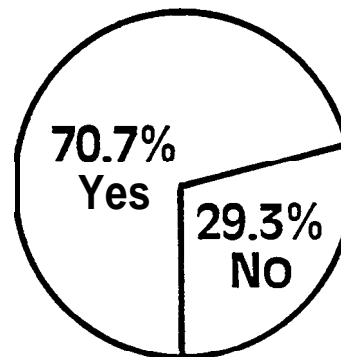


SYSTEMS INNOVATIONS

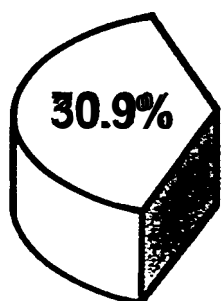


Base: 705

Effective?

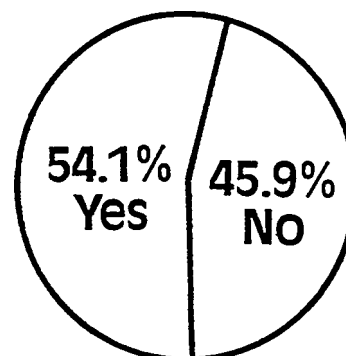


DEVELOPMENT OF INDIRECT LABOR STANDARDS AND CONTROLS



Base: 698

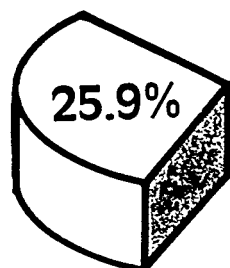
Effective?



ROBOT EFFECTIVENESS OFTEN RATED LOW

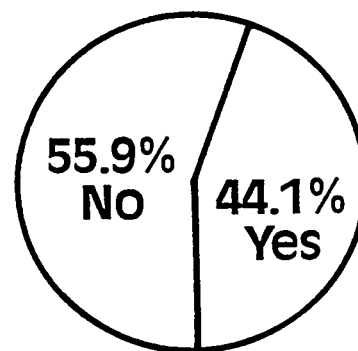
Questioning on capital investment for new or automated machinery (see page 4) pointedly excluded robotics in order to get an isolated reading on this advanced concept as a productivity activity. One-fourth of respondents said robotics were among their facilities' investments, and this differs little from the previous year's survey. What is surprising, however, is that more than half of these reporting IEs (55.9%) said robots were not effective.

INTRODUCTION OR EXPANSION OF USE OF ROBOTICS

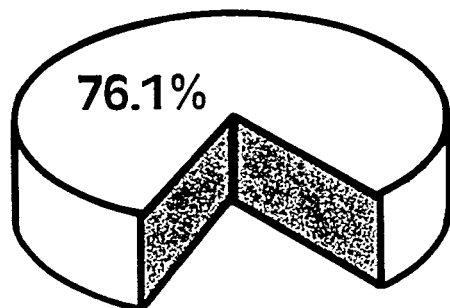


Base: 691

Effective?

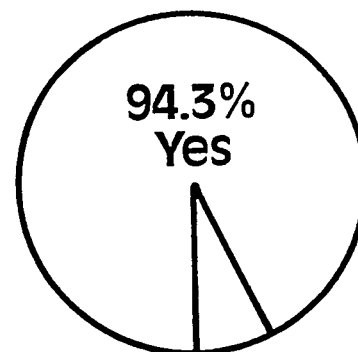


OTHER PRODUCTIVITY IMPROVEMENT METHODS



Base: 46

Effective?



5.7%
No

PRODUCTIVITY HAS MANAGEMENT OBSTACLES

Authorizing sufficient manpower to direct productivity improvement usually won't take place unless management understands *how* productivity can be improved. With this premise, it stands to reason when IEs were asked to designate obstacles facing productivity success they would give these two points about equal blame.

Also considered serious obstacles by more than half of the respondents were insufficient training programs, management failing to apply proper measurement programs and an inability of labor and management to work toward common productivity goals. With interest rates having leveled off since the last survey, fewer than a third saw high interest rates squeezing capital investment as a major obstacle.

Q: To what extent do you think the following are obstacles to productivity improvement?

**MANAGEMENT FAILING TO
UNDERSTAND HOW
PRODUCTIVITY
CAN BE
IMPROVED**

67.3%
Base: 739



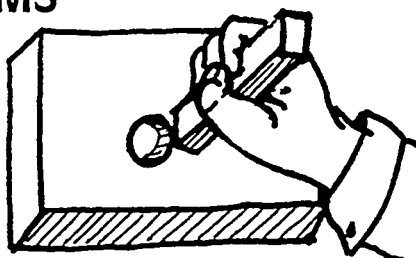
**MANAGEMENT FAILING TO
AUTHORIZE SUFFICIENT
MANPOWER TO DIRECT
PRODUCTIVITY
IMPROVEMENT**

61.7%
Base: 750



**INSUFFICIENT TRAINING
PROGRAMS**

57.2%
Base: 697

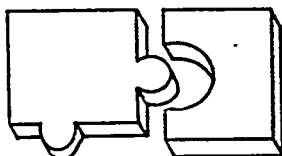


56%
Base: 734

**MANAGEMENT FAILING TO
APPLY PROPER
MEASUREMENT**

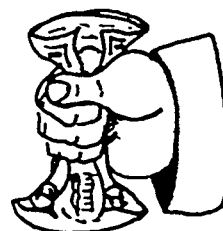
**INABILITY OF LABOR AND
MANAGEMENT TO WORK
TOWARD COMMON
PRODUCTIVITY
GOALS**

55.7%
Base: 736



HIGH INTEREST RATES

32%
Base: 735



W O R K A T T I T U D E S A F F E C T I N G

P R O D U C T I V I T Y ?

Five additional categories were posed for judgment by the “productivity engineers” who are in a position to witness such things day by day at work sites in plants, offices and other locations. Their observation: compared to ten years ago, employee loyalty, pride in work, workmanship, motivation is down. Less than 21 percent felt people work harder than a decade ago.

Looking at worker attitudes in still another way the picture painted in this survey differed a little. 56.8% of locations describe workers as “enthusiastic and optimistic.” This was five points higher than last year’s survey, but certainly still not an overwhelming majority.

Are these attitudes part of the human resources problem related to productivity improvement?

If so, then responses to another survey question should be studied closely by management. Asked how people might be encouraged to generate ideas to improve performance, personal recognition was considered much more important than either monetary reward or opportunity for promotion.

Q: Compare the following now with ten years ago:

People work:

Base: 720

20.4 %
Harder



47.4 %
About
Same



32.2 %
Not as
Hard



Pride in work is:

Base: 722

22.4 %
Greater



35.3 %
Unchanged



42.3 %
Less



Employee loyalty is:

Base: 723

16.1 %
up



31.1 %
Unchanged



52.8 %
Down



Workmanship is:

Base: 726

33.3 %
Better



38.7 %
Unchanged



28 %
Worse



Work motivation is:

Base: 723

23.7 %
Greater



34.8 %
Unchanged



41.5 %
Less



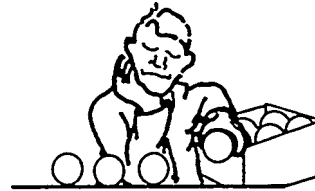
Q: Which of the following best describes the attitude of most of those who work at your location?

ENTHUSIASTIC AND OPTIMISTIC

-56.8%



Base: 73



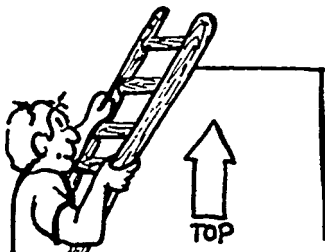
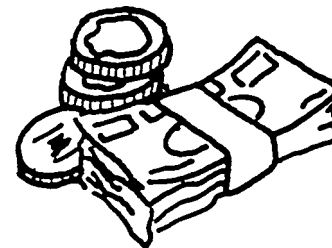
NOT VERY ENTHUSIASTIC AND
OPTIMISTIC - 43.2%

Q: What do you think is the single most effective way to encourage people to generate ideas to improve performance?



PERSONAL RECOGNITION - 55.2%

MONETARY REWARD - 29.2%



OPPORTUNITY FOR PROMOTION
- 16.3%

OTHER - 10.7%



Base: 765
(over 100% due to multiple responses)

WHAT ABOUT U.S. PRODUCTIVITY IN 1994?

Not many years ago, hardly anyone questioned American supremacy in productivity for the foreseeable future. But industrialization and new techniques in other countries have changed this view significantly, whether discussing the subject with IEs or the public at large.

Only a third of those surveyed this year believes the United States will rank highest in the world ten years from now. Nearly 46 percent puts the U.S. behind one other country (Japan and West Germany were most often identified) and another 21 percent saw the U.S. behind not just one but "most" industrial nations. A positive note: the percentage of IEs seeing the U.S. still on top in 1994 was a few points higher than those holding this opinion in the previous survey and substantially higher than three years ago when only 20% believed Uncle Sam would maintain its productivity edge for 10 years.

Q: What is your opinion on U.S. productivity ranking ten years from now?



**HIGHER THAN ALL OTHER INDUSTRIAL
NATIONS – 32.6%**

**HIGHER THAN ALL BUT ONE OTHER*
INDUSTRIAL NATION – 45.9%**

**LOWER THAN MOST OTHER
INDUSTRIAL NATIONS – 21.4%**

**LOWER THAN ALL OTHER INDUSTRIAL
NATIONS – 0.1%**

***OTHER NATIONS MOST OFTEN NAMED:**



**West
Germany
31.6%**



**Japan
92.3%**

TYPES OF INCENTIVE PROGRAMS REPORTED

Many companies have various types of employment incentives, but many are not setup as formal, ongoing programs. It was the latter which IEs enumerated in this survey. Wage incentive programs were by far the most prevalent; gain sharing incentive programs are still in a small minority.

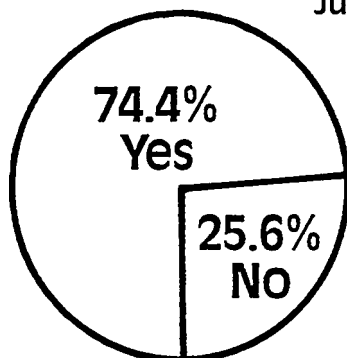
Besides being most popular in number, wage incentives also are the most effective, according to respondents. Nearly three-fourths thought the expense was justified. By contrast, most IEs at organizations where gain sharing programs are in operation do not think the expense is justified.

Increased worker efficiency was given as the single most important benefit of a formal incentive program, getting more responses than improvement of output quality, increased company loyalty and other benefits combined.

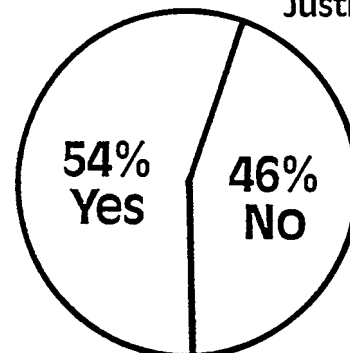
Q: Does your organization have a formal employee incentive program of the following types and is the expense of it justified?

	Has	%
WAGE INCENTIVE PLANS Base: 664	201	30.3
GAIN SHARING PLANS		
Improshare Base: 422	16	3.8
Rucker Base: 402	2	0.5
Scanlon Base: 405	6	1.5
Other Base: 348	56	16.1

WAGE INCENTIVE PLANS Is Expense Justified?



GAIN SHARING PLANS Is Expense Justified?



ROLE OF INDUSTRIAL ENGINEERS

With productivity gaining more and more attention in a competitive worldwide economy, the survey sought to determine if the productivity focus was being reflected in the careers of industrial engineers, who are the fulltime professionals in productivity improvement. Evidently this is the case, with 50.8 percent saying they're more influential in management decisions now than when first associated with their present employer. IEs see themselves with a lead role in developing sound organization productivity programs primarily because of the reasons identified in the chart below.

Most of the IE respondents (69%) work in manufacturing, but service industries, government, educational institutions and consultants were also represented. Present principal job function was divided mostly between manager (35%) and staff engineer (40.7%). How respondents were distributed in terms of size of organizations by whom they're employed is shown in the graph on this page.

Q: What are the primary reasons industrial engineers are best qualified for the lead role in developing sound productivity programs?

**BROADER PERSPECTIVE OF WORKFLOW
PRODUCTION AND SYSTEMS CONTROL**

80.9%

**EXPERIENCE AND TRAINING IN MANAGEMENT
TECHNIQUES BEYOND THAT OF OTHER
ENGINEERING DISCIPLINES**

65.4%

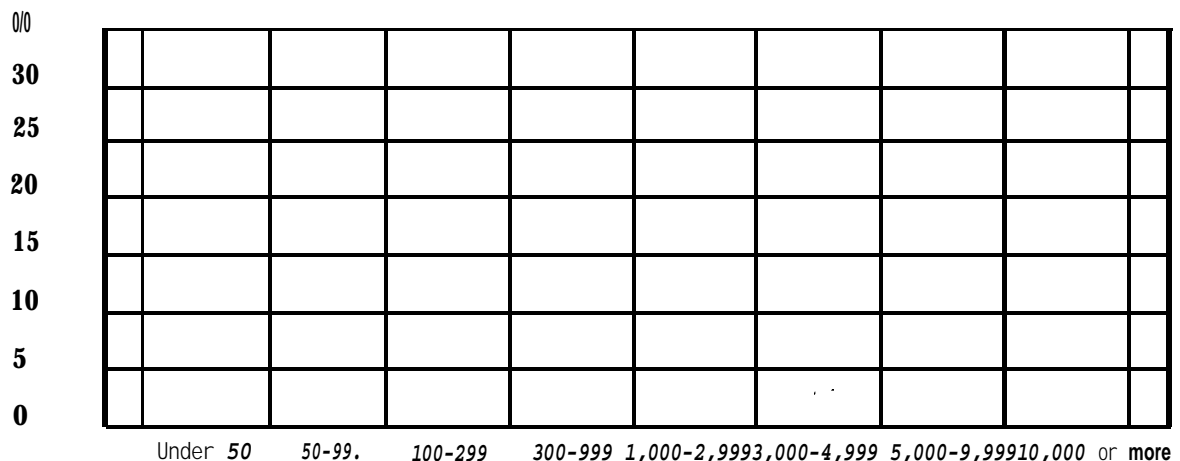
**ACADEMIC CURRICULA TEACH THE IE MORE
ABOUT THE RELATIONSHIP OF HUMAN
RESOURCES TO TECHNOLOGY**

44.3%

Base: 677
(over 100% due to multiple responses)

OTHER 5.8%

Q: Approximately how many persons work for the firm or organization at the location where you have your main job?

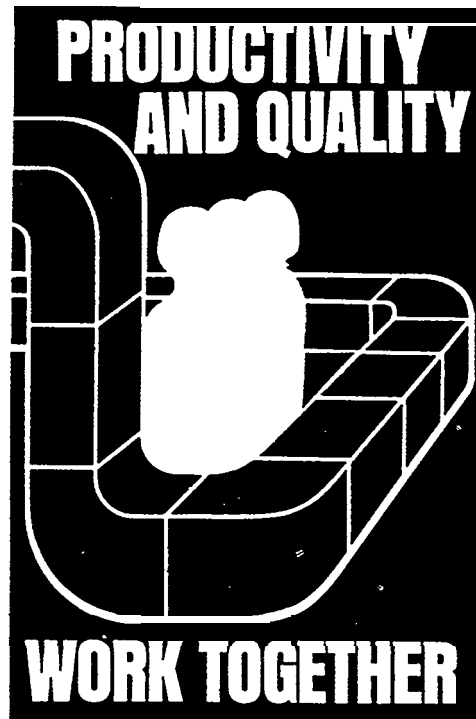


SPECIFIC IMPROVEMENT EXAMPLES ARE AVAILABLE

Undoubtedly productivity improvement is becoming the primary goal of organizations everywhere. And the annual survey does more than monitor the extent of PI programs; it also gathers and makes available examples of specific programs successfully undertaken in industry, business and institutions of all sizes. Measured in either reduced dollar expenditures, saved manhours – or both, these examples submitted by a representative number of survey respondents are available to organizations needing comparative tools and references while formulating or revising their own PI programs (see order form below).

Notes on the 1984 survey: questionnaires were mailed to 2,500 non-student U.S. members of the Institute of Industrial Engineers on an Nth number selection basis. Valid responses numbered 765 for a response rate of 30.6%.

The survey is among projects of the Institute's annual Productivity Improvement Campaign, conducted as a public service to forward productivity development throughout the economy. "Productivity and Quality Work Together" is the 1985 campaign theme. Organizations wishing to display posters and distribute employee leaflets which explain how productivity relates to their own well-being may use the order form below.



The Institute of Industrial Engineers is a non-profit international professional society of 43,000 members whose principal endeavor is productivity improvement, encompassing design and installation of integrated systems of people, materials, equipment and energy.

MAIL TO:



**INSTITUTE OF INDUSTRIAL ENGINEERS
25 TECHNOLOGY PARK/ATLANTA
NORCROSS, GEORGIA 30092**

Send the following:

- ☐ _____ additional copies of this survey report @ \$1 each. Quantity discount price: \$.75 for more than 5 copies. \$ _____ enclosed.
- ☐ Price information on the employee leaflet explaining productivity's impact on pay-checks and job security.
- ☐ Price information on the bulletin board poster sheet with the 1985 PI Campaign theme, "Productivity and Quality Work Together."

Name _____ Title _____

Organization _____

Address _____

City _____ State _____ Zip _____



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